AGILE

INTEROPERABILITY STRATEGIES FOR PUBLIC SAFETY

A program of the National Institute of Justice

Guide to Radio Communications Interoperability Strategies and Products

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1 INTRODUCTION

Interoperability is the ability of public safety service and support providers—law enforcement, firefighters, EMS, emergency management, the public utilities, transportation, and others—to communicate with staff from other responding agencies, to exchange voice and/or data communications on demand and in real-time. It is the term that describes how radio communication systems should operate between and among agencies and jurisdictions that respond to common emergencies. However, different jurisdictions and agencies often use incompatible equipment and radio frequencies, and as a result, very often they cannot communicate with one another.

Radio communications interoperability is a critical need, whether in response to a major incident, routine task force operations or providing a coordinated response to daily events. There are several strategies that agencies can implement to facilitate interoperability. This document defines three overall technical strategies for providing interoperability and identifies products that are available today that can be used to implement those strategies. These strategies include:

1) Create one radio system that provides communications for multiple agencies;
2) Establish a common frequency and (if necessary) protocol so that transmissions from a subscriber on one radio system can be received by subscribers on a different radio system; and
3) Deploy a gateway device that establishes an interface between radio systems by receiving a transmission from one radio system and rebroadcasting it on another radio system (typically on a different, normally incompatible, frequency).

The purpose of this document is to describe these different strategies and to characterize the products that are currently available to implement those strategies. While this guide does not include specific product evaluations, it does explain different categories of products and provides information on the features and capabilities offered by the various products. This information provides the public safety community with a way of sorting through the products arriving on the market to determine what type of solution best meets their requirements. NIJ has not conducted a comprehensive analysis of all of these products, and any performance information is based on vendors' published performance specifications.

Note that implementing the technical strategies documented in this report is only part of the overall approach to achieving interoperability. A comprehensive approach to interoperability also requires governance, planning, funding, training, and operational policies.[1]

Section 2 of this document outlines the need for communications interoperability and the reasons that radio systems can be incompatible. A discussion of different technical approaches to interoperability is provided in Section 3. Sections 4 and 5 provide details on product characteristics. The report methodology, references, and disclaimers are included as appendixes to this report.

[1] A recommended resource on these other issues is the February 2003 report published by the National Task Force on Interoperability entitled *Why Can't We Talk: Working Together to Bridge the Communications Gap to Save Lives*.

2 NEED FOR INTEROPERABILITY

Interoperability problems associated with communications among multiple agencies have been evident for years, and have received significant publicity in the wake of national tragedies such as the terrorist attack on the World Trade Center[2] and the Pentagon[3], the shootings at Columbine, and the bombing of the Federal Building in Oklahoma City. While the scope and magnitude of the casualties in these incidents underscore the consequences of the failure of agencies to communicate, it is important to note that communications interoperability is important to every first responder, and is an important aspect of any law enforcement or public safety agency's daily operations as well.

Interoperability is critical during incident response situations in which multiple agencies, often including multiple functions (e.g., law enforcement, fire, EMS), respond to a specific incident. Incident response scenarios can include terrorist attacks; natural disasters such as wildfires, tornados, hurricanes, and earthquakes; and hazardous materials incidents.

Interoperability is also necessary in mutual aid situations in which one agency is called to assist another agency. Examples include a vehicle pursuit that enters another jurisdiction and responses when an agency crosses a jurisdictional boundary because it has vehicles closer to the location of a crime in progress (such as a county sheriff's deputy responding to a robbery at a bank near a city/county line).

Multi-agency task force operations also require communications interoperability. Examples include counter narcotics and organized crime task forces, Presidential/VIP escort and protection, and other activities. Task force operations are planned activities in which agencies and personnel are routinely assigned to work together for a specific operation or non-emergency response.

However, when agencies from different or multiple jurisdictions need to mount a coordinated response, they may not be able to communicate with each other via their radios because their radio equipment is incompatible. Public safety radio systems operate in different frequency bands (like the AM and FM bands of a radio). Just as an AM radio cannot pick up an FM radio station, public safety radios in one frequency band cannot pick up transmissions in another frequency band. As a consequence, when responding to a major incident, agencies must cope with other, inefficient, means of communications (such as relaying messages through multiple dispatchers, or using runners to hand-carry messages). The advent of more sophisticated radio systems such as digital trunking systems can compound this problem if agencies are using different systems. Digital trunked radio systems are designed and manufactured so that, even if two such radio systems are both operating in same frequency band, broadcasts from one manufacturer's radio cannot be heard by another manufacturer's radio, or vice versa.

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[2] NY Times, "Fatal Confusion," 7 July 2002.
[3] Arlington County After Action Report on the Response to the September 11 Terrorist Attack on the Pentagon.

3 INTEROPERABILITY STRATEGIES

There are a number of strategies to achieving interoperability among personnel of multiple agencies using their radio system:

1) Create one radio system that provides communications for multiple agencies;
2) Establish a common frequency and (if necessary) protocol so that transmissions from a subscriber on one radio system can be received by subscribers on a different radio system; and
3) Deploy a gateway device that establishes an interface between radio systems by receiving a transmission from one radio system and rebroadcasting it on another radio system (typically on a different frequency).

A taxonomy of strategies is shown in Figure 3-1; each of these strategies is outlined in a subsection that follows.

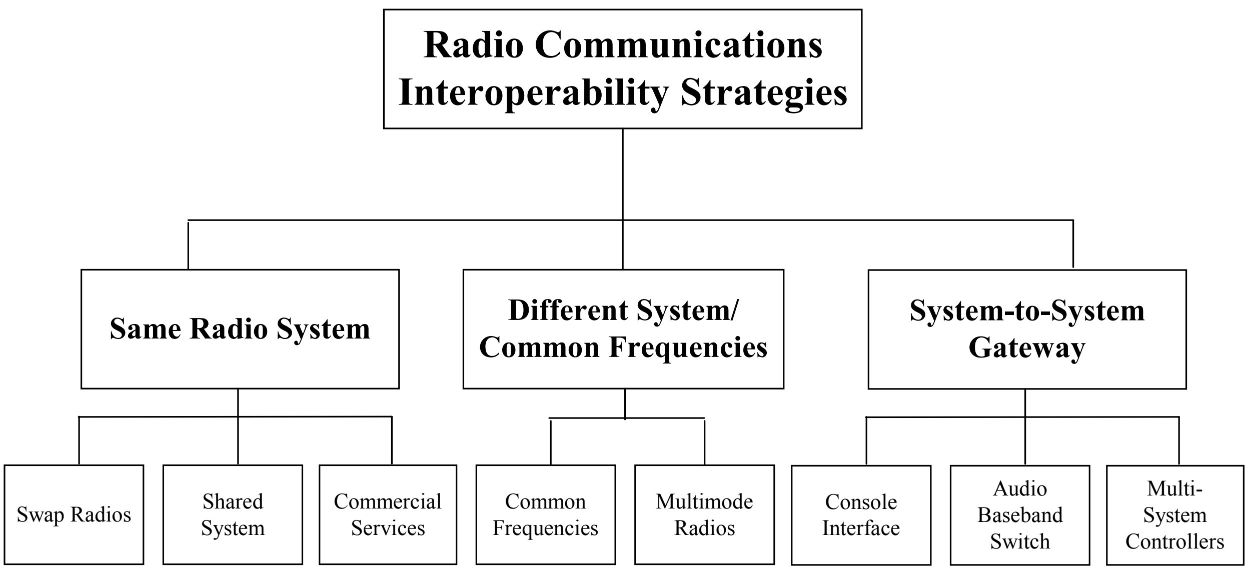

Figure 3-1: Interoperability Approaches

3.1 Same Radio System Strategy

The most effective way to achieve interoperability is to have all users on a single radio system. All users on the system, regardless of agency, can communicate if they are all subscribing to the same radio system. This can be accomplished on an ad hoc basis by providing radios on a temporary basis, or by creating a system that is designed for users from multiple agencies, or by using commercial services. Each of these approaches is described in a subsection that follows.

3.1.1 Swap Radios

One way of achieving interoperability is to provide users with radios on a temporary basis. For example, during task force operations, one agency may simply provide all personnel detailed to the task force (including those from other agencies) radios. Personnel then use those radios for communications among task force members, and may need to carry a second radio to communicate back to their own agency. The cost of this approach is the cost associated with having a sufficient number of radios available for distribution to task force members.

A similar approach can be used to provide radios to agencies responding to a major incident. Several agencies have pre-positioned caches of radios that can be distributed in the event of an emergency; for example, on September 2001, although not planned, Montgomery County, Maryland, had a shipment of radios in storage in anticipation of installation of a new radio system. These were deployed to agencies responding to the terrorist attacks on the Pentagon and World Trade Center. (The Council of Governments in the Washington area has since proposed the purchase of a cache of radios for use in response to a major incident.) An important element of this approach is the ability to rapidly reprogram the radios for the radio system that is being used (for example, using field-cloneable radios). Another important consideration is to ensure that the batteries are charged and sufficient chargers are available so that the batteries can be recharged as quickly as they are used. Since the radios must be brought to an incident scene and distributed, this approach is effective for incidents that involve a buildup of responders over a period of hours or days; examples include responses to wildfires, floods, and so on.

3.1.2 Shared System

Swapping radios or pre-positioning radio caches provides interoperability on a temporary, as-needed basis. A permanent interoperability solution can be achieved by building a single radio system that serves multiple agencies. Such systems are typically built for a county, a region, or across a state. These systems are referred to as "shared systems," as multiple agencies (and typically jurisdictions) share the expenses and the benefits of a single system. Multiple agencies pool resources and deploy a communications system that meets their collective requirements. In particular, trunked systems can be configured to allow agencies to have their own talk groups, allowing them to communicate as if they had a system dedicated to their agency when appropriate, and allowing interagency talk groups to be utilized when interoperability is required.

The products associated with a shared system are the same products associated with a single agency public safety radio system (and are not listed in this report).[4] What distinguishes a shared system for interoperability from a single agency's radio system is the system governance and funding (since the system is supporting multiple agencies). The Public Safety Wireless Network (PSWN)[5] program has developed a number of resources for agencies considering the process of deploying a shared system.

If achievable, shared systems provide the greatest level of interoperability among agencies. However, shared systems involve significant costs and time and require that multiple jurisdictions and governmental agencies agree to a set of common requirements that would define such a system. The cost of replacing existing equipment is too high for many agencies; especially considering that operating characteristics of systems built in different frequency bands may require additional equipment and towers. In addition, characteristics of different frequency

[4] For a listing of radio communications products, see "Guide for the Selection of Communications Equipment for Emergency First Responders," NIJ Guide 104-00, February, 2001, available from the National Institute of Justice at http://www.ojp.usdoj.gov/nij/pubs-sum/1911601.htm.
[5] www.pswn.gov.

bands are such that the best solution for one agency may not be the best solution for another agency (characteristics of different frequencies are such that some operate more effectively in urban areas, others in rural areas, and so on). Finally, frequencies may not be available to support all agencies in a single band.

3.1.3 Commercial Services

Commercial services[6], while widely used for everyday non-critical communications by public safety agencies, have, until recently not been considered as an alternative to a privately owned land mobile radio system[7] (LMR), with the exception of commercial leased systems. Commercial services generally fall into one of the following categories.

- Specialized Mobile Radio (SMR), a commercial wireless service such as NEXTEL that may provide mobile dispatch and data communications services. Users of SMR systems can communicate between single radios or simultaneously to a group of users. Interoperability within the SMR service falls under the "single system strategy." Unfortunately interoperability outside of the service may be limited due to the lack of common standards and protocols, which is further compounded by the fact that SMR systems are licensed across three different frequency bands (220 MHz, 800 MHz and 900 MHz).[8]
- Leased Land Mobile Radio (LLMR), commercial systems built, maintained and managed for the sole purpose of providing a fee-for-service arrangement. LLMR systems are similar in design to privately owned LMR systems and share the same interoperability challenges as the private systems. Interoperability is dependent on system design and capability and is usually limited to only users on the system.
- Mobile Satellite Service (MSS), in the US commercial satellite service is available through the American Mobile Satellite Corporation. The service offers digital broadcast capability, which allows the dispatcher to speak to a single user, a group of users or all network users. Users can in turn communicate with members of any one of 16 predefined talk groups supporting up to 10,000 subscribers. Users within a talk group can communicate via a one-way group call or through standard two-way communication. Interoperability is provided only between users of the system or to individuals connected to the public switch telephone network.

3.2 Different System/Common Frequency Strategy

A second strategy is for subscribers of different radio systems to communicate on a frequency common to both radio systems. One approach is to identify a mutual aid or interoperability channel. Many agencies have found that interoperability between local or state agencies from a technical aspect is achievable by reprogramming existing radios with each others' frequencies (channels). In other cases, even if agencies operate on different bands,

[6] Commercial mobile radio service by definition is a mobile service that is provided for profit, i.e., with the intent of receiving compensation or monetary gain; an interconnected service; and available to the public, or to such classes of eligible users as to be effectively available to a substantial portion of the public.
[7] Commercial services are routinely chosen to provide data services and as mean of backhaul for LMR systems.
[8] Additional Information on SMR/LMR or MSS systems can be found at the PSWN library http://www.pswn.gov/library.htm.

interoperability may be available, through the use of dual or multi band radios, which are capable of operating on two or more bands independent of each other. Each of these approaches is described in a subsection that follows.

3.2.1 Common Frequencies/Channels

One strategy is to program radios belonging to different radio system regionally or nationally to operate on a common channel. Certain designated mutual aid or interoperability frequencies can be programmed into radios for all agencies. Then, as long as all radios are in the same frequency band, users can select the designated channel to communicate with users from other agencies. Such channels are often used as talkaround channels. This approach is used today in many circumstances, but is limited by the requirement for all users to be in the same frequency band, and that a single interoperability frequency can rapidly become congested during a major event.

A similar approach can be implemented when an agency defines a channel or channels that can be programmed into other agencies' radio systems and used as a common channel. This allows personnel from an agency to communicate on another agency's system, directly with other agency personnel. Typical radios in operation today can be configured in this way if the agencies' radio systems must operate in the same frequency band with no proprietary restrictions, or operate compatible proprietary systems (e.g., developed by the same manufacturer using the same protocols). This approach, accompanied by extensive preplanning and training, was crucial in the ability of the local first responders in northern Virginia to communicate in response to the September 11, 2001 attack on the Pentagon.[9]

One approach to ensuring the compatibility of radios operating on a common frequency is use of a standard protocol that is implemented by various manufacturers. The P25 standard[10] ensures that radios that comply with the standard can communicate with other P25 radios operating on the same frequency regardless of radio manufacturer.

3.2.2 Multiband/Multimodal Radios

There are also radio products that are specifically designed to provide interoperability by providing the capability to operate on multiple frequency bands and/or in multiple modes, such as dual-band radios and tunable multi-band transceivers. A subscriber can therefore access multiple radio systems.

Dual-band radios are characterized by two transmitters and receivers designed into one (radio) case or two radios with one control head, with the ability to receive and transmit on frequencies in both bands. Dual-band radios operate the same as a single band radio with the exception of being able to physically switch between two distinct bands. Dual-band radios allow the operator to monitor (scan) different frequency bands, such as VHF and UHF, and then select one or the other band during transmissions.[11] Interoperability is therefore possible between agencies that utilize frequencies that fall within the range of the two frequency bands of the dual-

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[9]For more details, see "Answering the Call: Communications Lessons Learned from the Pentagon Attack," January 2002, published by the Public Safety Wireless Network (PSWN) and available at www.pswn.gov, under the Coordination & Partnerships section of the Library.
[10] Information on the P25 standard can be found on the Website of APCO International (www.apcointl.com).
[11] Design limitations of public safety dual-band radios prohibit the simultaneous transmission over both bands.

band radio as illustrated in Figure 3-2. One main advantage of this method of interoperability is the efficient use of radio spectrum. Spectrum efficiency is maintained by keeping the radio nets separated and only transmitting on the radio net that is required, unlike crossbanding, which ties nets together and increases radio congestion.

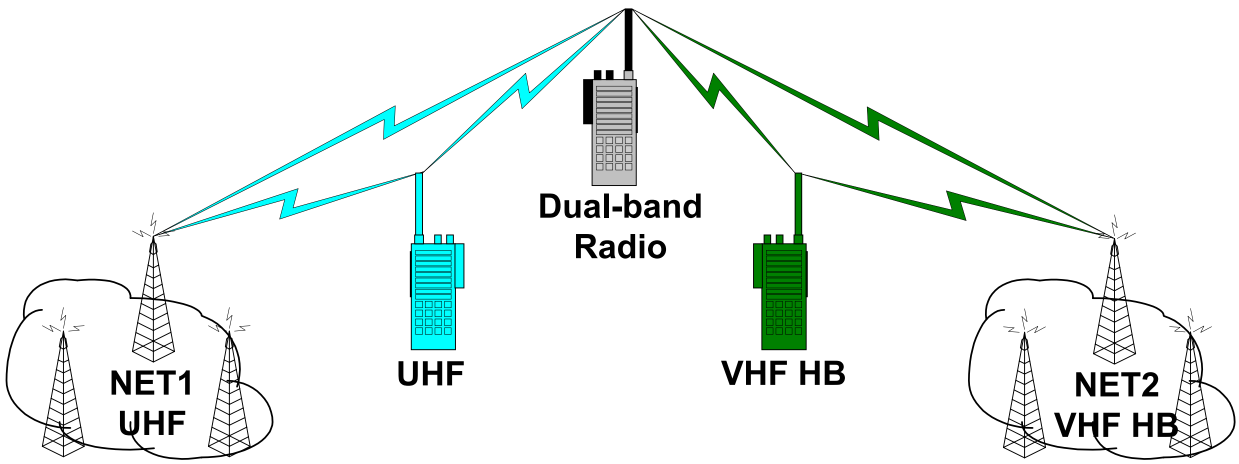

Figure 3-2: Dual-band Interoperability

Unlike retransmission systems, dual-band radios do not link radio systems; thus in the example shown in Figure 3-2, a user on Net 1 with only a UHF radio would not be able to communicate with a user on Net 2 with only a VHF radio. Note also that currently the only public safety bands supported are in the VHF high-band and UHF frequencies, limiting the applicability of this strategy. Table 3-1 lists commercially manufactured dual-band radios available in public safety frequencies.

Table 3-1: Dual-band Radios

Manufacturer	Product	Frequency Bands	Channel Capacity	Mobile/Portable
Vertex	FTH-2070	VHF HB - UHF	32	Portable
	VX-4000[12]	VHF LB/HB - UHF	250	Mobile
Kenwood	TK-790/890(H)[13]	VHF HB - UHF	160	Mobile

Tunable multi-band transceivers (radios) provide an alternate solution to carrying multiple radios or crossbanding frequencies together. They are characterized by one transmitter and receiver (radio) capable of tuning across multiple bands, with the ability to scan across all programmed frequencies. Multi-band radios allow multiple channels to be programmed to receive and transmit in different frequency bands such as HF, VHF Low-band, VHF High-band, and UHF radio as illustrated in Figure 3-3. These products cover a broader range of frequencies

[12] Utilizes two radios and one control head to achieve dual-band capability.
[13] Same as above.

than dual-band radios, but are more expensive. The benefit of a tunable multi-band radio, able to scan across a wide spectrum, is the ability to monitor different frequency bands while keeping radio nets separated and preventing nets from becoming over saturated with transmissions. Table 3-2 lists tunable multi-band radios.

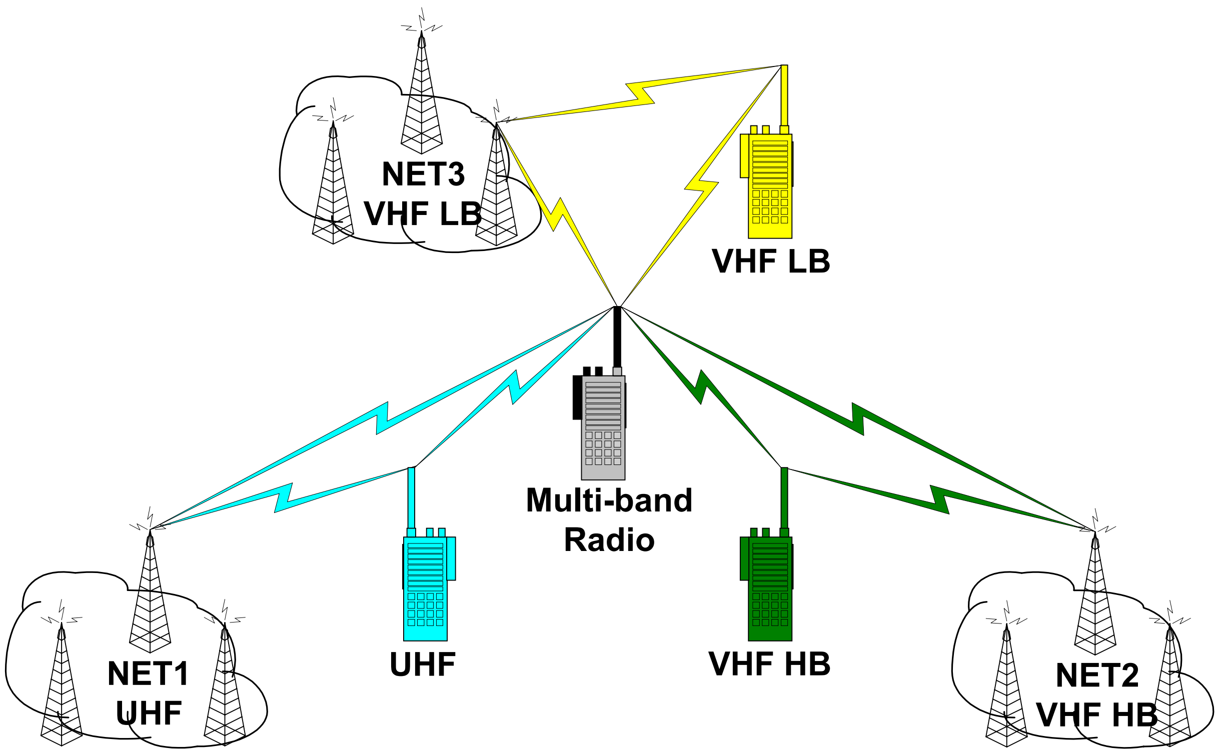

Figure 3-3: Multi-band Interoperability

Table 3-2: Multi-band Radios

Manufacturer	Product	Frequency Range (MHz)	Channel Availability	Mobile/Portable
Harris	RF-5800V	30-108	25	Mobile
	RF-5800M	30-512	100	
Thales	MBITR (AN/PRC 148)	30-512	100	Portable
Wulfsberg	Flexcomm™II RT-5000	29.7-960	30	Airborne[14]

3.3 System-to-System Gateways

An alternative to a same radio or common waveform approach is to link separate systems by deploying a capability that receives a transmission on one radio system and retransmits it on a different radio system (often on a different frequency band). This strategy can be implemented without significant additional infrastructure, and without significant modifications to radio

[14] APCO Project 25 Compliant.

systems being linked. The disadvantage of this approach is that it requires a frequency (channel) to be tied up for each different radio system when in use, that is part of the link.[15] However, given the relatively low cost of retransmission devices (compared to implementation of a new shared system) and the fact that devices that rebroadcast can be deployed with little or no changes required to existing radio systems, this approach has significant potential, particularly as a near-term solution or as part of a transitional strategy.

The architecture of such systems can range from simple mobile repeaters to complex gateway communications systems. They are all based on the general principle of using a system that receives a radio transmission on one frequency and transmits the audio to one or more other agencies using the frequencies of the other agencies' radio channels. (The term "crossband" indicates that these devices most commonly are used to rebroadcast a transmission in a different frequency band; however, such devices can also rebroadcast within the same frequency band. The concept of operation is basically the same regardless of whether the rebroadcast frequency is within the same band or in a different band.)

This section describes classes, and in some cases subsets, of system-to-system gateway (retransmission) devices:

- Console patch; and
- Audio baseband switch.

3.3.1 Console Patch

Console patches are circuitry, controlled either through a software user interface or manually, that can patch together two or more audio signals at a communication or dispatch center. They provide the physical means of connecting two or more audio circuits (from radios and/or commercial phone lines) together and allow communications among radios and telephone equipment. Early patch panels required an operator or dispatcher to physically connect two circuits by inserting a patch cord into each circuit's corresponding connector, which was usually located on the front of a patch panel (from which the name is derived). Patch panels, in combination with a communication console, provide another method of communications interoperability that has been used by public safety for many years. Unlike a crossband repeater, patch panels require that a wired audio circuit from each agency is physically present at a centralized console. Modern dispatch consoles use switches controlled by microprocessors that are capable of adjusting for hi/lo impedance and receiving a balanced or unbalanced audio signal. Dispatchers can interconnect circuits, from their dispatch terminal between conventional radio systems, trunked radio systems, and/or telephone circuits. Table 3-3 lists communication consoles available for use by public safety agencies.

There are several variations in how this strategy can be implemented. In some cases the interoperability link is made through a single dispatch console to another dispatch console. In other cases it may be sufficient to patch in a subscriber unit of one radio system to the communications console of a second radio system. In the interoperability example that follows,

[15] A channel link can effectively increase call volume on one channel from each of the linked systems for the duration of the link. While channel linking is relatively easy from a technical perspective, care must be exercised to not create operational issues as a result of linkage. This type of interconnection must be accompanied by well-planned operational changes so as to not overwhelm the interconnected channels with traffic or intermix incompatible departmental procedures.

the interoperability link is made from one agency's dispatch center through a central hub to a second agency's center.

Table 3-3: Communication Consoles

Manufacturer	Product	Number of Channels/Lines	Radio to Radio Patch	Radio to Telco Patch
Avtec	DSPATCH 32	32	Yes	Yes
	DSPatch	2048		
	DSPatchNET	4096		
Baker Integrated Tech.	DISPATCHWorks	96/144	Yes	Yes
Compunetix Inc.	CONTEX® 60T	60	Yes	Yes
	CONTEX® Mini T	400		
	CONTEX® 500T	600		
	CONTEX® 1000T	1920		
	CONTEX® 2000T	2400		
Cyfas Systems	CX2000-NT	125	Yes	Yes
	C10	10		
GAI-Tronics® Corp.	Comtegra Console	192/12	Yes	Yes
	CommandPlus Console	192/12		
General Devices	NetManager™	Unavailable	Yes	Yes
M/A-COM	C3Maestro	112	Yes	Yes
Moducom	UltraCom Radio/E911	247	Yes	Yes
Motorola	CENTRACOM Elite	60-120	Yes	Yes
Orbacom Systems	TDM 25	8	Yes	Yes
	TDM Modular	120		
	TDM Series CRT	Unlimited		
REDCOM Inc.	DCCX	240	Yes	Yes
Safetran Systems	DTX	240	Yes	Yes
Telex/Vega	C-6124	12	Yes	Yes
	C-6200	18		
Zetron	M4010	12	Yes	Yes
	M4020	20		
	M4048	48		
	S4000	20/48		

Manufacturer	Product	Number of Channels/Lines	Radio to Radio Patch	Radio to Telco Patch
	Acom Adv. Comm Sys.	1500		

Interoperability Example: San Diego, California (BORTAC[16])

In 1995, the Border Research and Technology Center (BRTC), a program of the National Institute of Justice (NIJ), undertook the task of improving law enforcement agency radio interoperability in the San Diego area at the request of the U.S. Attorney for the Southern District of California. In collaboration with the Office of National Drug Control Policy (ONDCP) Counter-drug Technology Assessment Center (CTAC), BRTC, the U.S. Navy, and area law enforcement designed and implemented real-time, unencrypted voice communication improvements while preserving the autonomy of each participating agency. The implementation uses off-the-shelf communications circuits and radio system software to create a "patch" that connects different agencies' radio systems. To establish a connection between two agencies, dispatchers at both agencies must patch the appropriate radio channel to the circuit linking the agency's dispatch center to the central BORTAC site. A dispatcher there then must link the two voice circuits to complete the radio-to-radio connection. Note that each user has to be operating within the existing coverage of his or her radio system.

The result is a "hub and spoke" arrangement where participating agencies are connected to a radio system console "hub" by voice grade telephone circuits. This capability allows Federal agencies to communicate with various combinations of State and local public safety agencies. Officers are able to speak directly to one another. The result is more accurate exchange of information and more timely response by each officer.

The names of the participating agencies are displayed on a central computer screen. When two or more agencies request that they be connected, a dispatcher at the central location uses a mouse to connect the appropriate icons on the computer screen. The software connects the communication circuits into the equivalent of a conference call. In this case, the voices heard on the conference call are the audio portion of each agency's radio channel that has been designated for that patch.

Multiple agencies can be patched together and multiple patches can be operating independently of one another. When the agencies have completed the operation, they notify the central center and a dispatcher uses a few mouse operations to disconnect the participants. No agency is ever added to the patch unless that agency agrees. In this way, the autonomy of each system is preserved.

Since the system became operational in 1996, BORTAC has been used repeatedly by law enforcement in the San Diego area for an array of activities, including regional auto-theft task force operations, truancy sweeps, counterdrug sweeps, police pursuits, special cross-border events, and gang suppression. Based on the success of the original system, similar systems have been deployed in Imperial County, California ("BORTAC II") and Brownsville, Texas ("RIO-Com").

[16] BORTAC Communications "PATCH", Dr. Robert Waldron, Director, NLECTC-West and Chris Aldridge, BRTC

3.3.2 Audio Baseband Switch

An audio baseband switch typically extracts audio from a radio, then switches the audio to another radio and transmits the audio on a different radio system. By audio baseband, we refer to the fact that only the audio is passed through the switch; no system control information (other than push to talk) is passed through the gateway.

As shown in Figure 3-4, transmissions are (1) transmitted by a radio on one frequency, (2) received by another radio on that same frequency, (3) routed through the switch to a radio set to a different frequency, (4) rebroadcast on the second frequency, and (5) received on the second frequency.

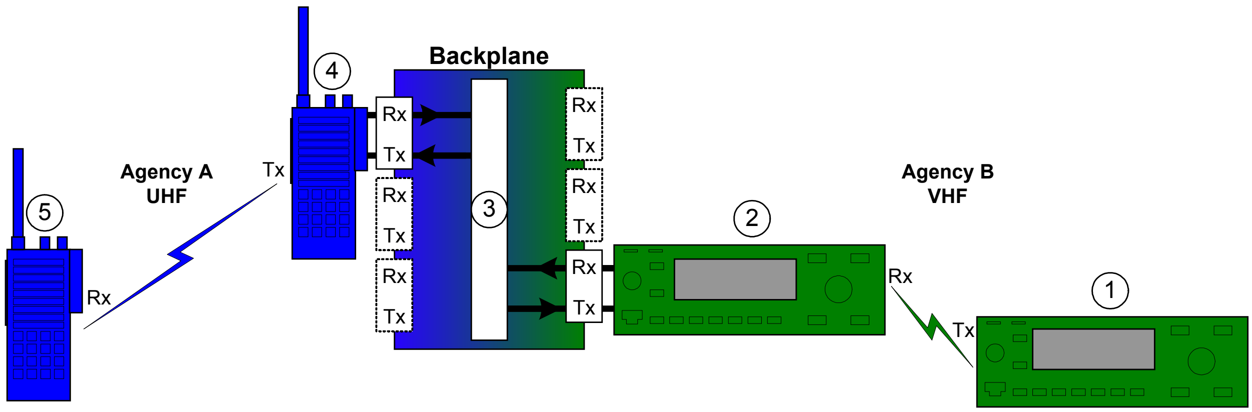

Figure 3-4: Generic Audio Baseband Switch

There is a wide range of such devices. The simplest devices are two channel crossband repeaters, which provide a simple connection from one radio to another. More sophisticated interconnect systems provide a variety of different features. Different products provide one or more of the following features: processing of audio for noise reduction, ability to program delays, buffers, linking of more than two systems, ability to maintain multiple connections simultaneously, and/or ability to create and break connections in real-time.

While audio baseband switches are configured with a variety of different features, there are some common characteristics that are significant in terms of their deployment for public safety applications:

Audio baseband switches all retransmit a voice communication on one or more other radio systems using one or more additional frequencies. In particular, that frequency/channel would then not be available for that agency's other operations and activities. Agencies with a limited number of frequencies/channels (for example, an agency with two frequencies, one used as an administrative channel and one used as a tactical channel) must plan carefully for circumstances when one channel is devoted to interoperable communications with other agencies.

Although not shown in Figure 3-4, audio baseband switches can be used to link repeater-based systems. Care must be taken to ensure that delay times are incorporated into the gateway architecture to avoid a "ping pong" effect. Ping-pong occurs in bridged systems when a radio interfaced to an audio baseband switch is transmitting to a receiver site through a repeater. Due to the length of the repeater squelch tail, a repeater could stay up long enough to key a radio interconnected via the audio baseband switch before the originating network repeater keys down.

Then because the radio is keyed up, the process repeats in the reverse direction (thus back and forth like a ping-pong ball) and so on. This effect can be eliminated either by configuring gateway audio delay times and repeater squelch tails. Since the repeaters in existing systems are generally programmed to optimize performance of the system (rather than accommodating the gateway interface), it is preferable that the gateway switch audio delay be configured to accommodate the existing repeaters, rather than requiring repeater squelch tails to be reprogrammed to support the gateway.

Audio baseband switches can handle interfaces between two systems that use encrypted communications, although end-to-end encryption is not supported. In cases where secure (encrypted) communications is employed, the transmission from a subscriber (if necessary through a repeater) to radio attached to an audio baseband switch is encrypted. The radio attached to the audio baseband switch decrypts the transmission and routes clear audio through the switch backplane to another agency's radio. The audio is then re-encrypted by the second agency's radio, re-transmitted (through the second system's repeater if necessary) to the receiving unit (which decrypts the signal for the user). Figure 3-5 depicts an example scenario that was implemented under the AGILE program for the Syracuse, New York, Police Department, using an ACU-1000 for the audio baseband switch. The red arrows between the radios and the switch itself represent clear audio within the gateway itself. Note that for many public safety applications this architecture, combined with some physical security around the switch itself, is adequate.

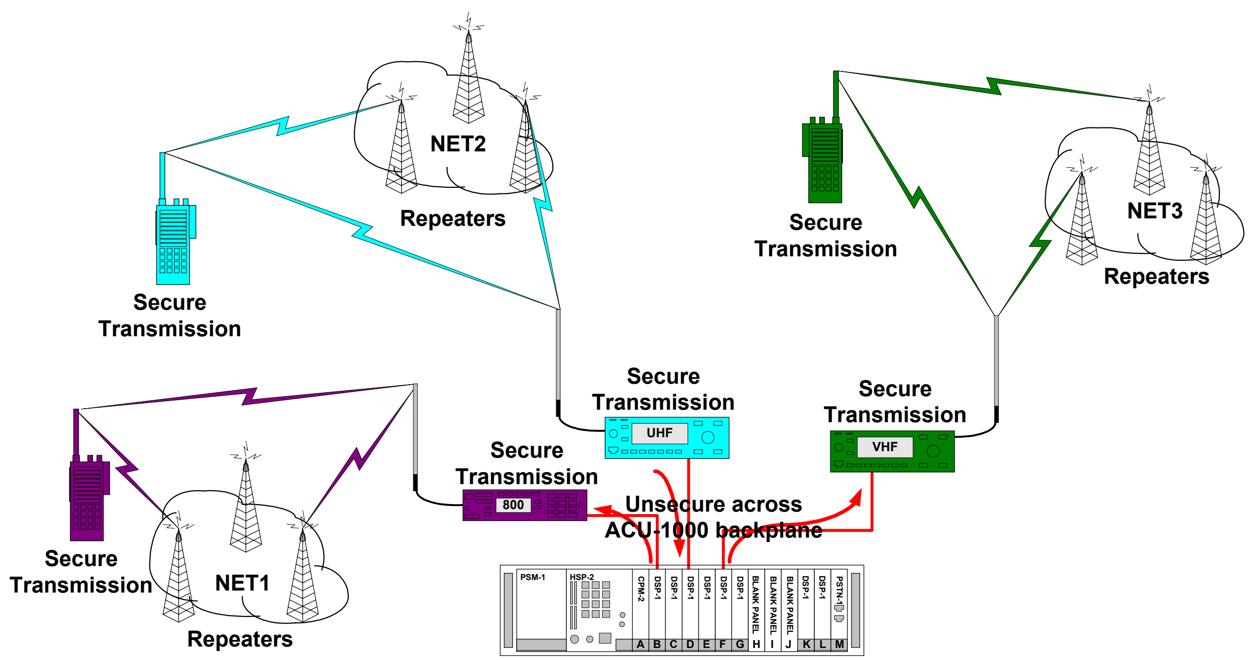

Figure 3-5: Secure Mobile Interoperability System

Particular care must be taken when using an audio baseband switch to link to one or more trunking systems. If a trunked system connected to a switch is experience heavy loading, the retransmission from the switch may be blocked and not be transmitted out on the target trunked system; since only audio baseband (and no control information) is passed through the switch, there is no way to notify the originator of the communications that the transmission was blocked on a target system. Operational acknowledgement protocols as well as monitoring of trunked systems are recommended to avoid situations in which a transmission is not transmitted as expected.

Audio baseband switches can be deployed as portable/mobile devices, or can be installed at a fixed site. A mobile deployment is more appropriate for responding to major incidents over a large geographic area of responsibility. For example, an agency that covers a county or regional area that requires a switch for responding to fires could use a mobile unit. However, a mobile unit must be deployed to operate, so it does not provide “on demand” interoperability for situations such as a vehicle pursuit. A fixed site switch is more appropriate for law enforcement operations where agencies have overlapping or adjacent jurisdictions. A link between multiple agencies can be created either from the field or by making a call to dispatch, so that interagency communications can be initiated immediately in response to an incident. Disadvantages of fixed site implementations include the following: the switch must be within the coverage area of the participating agencies, or linked via an audio line; and licensing issues are more restrictive for fixed sites. Some agencies have implemented deployable switches such that they are normally hooked up to fixed antennas in a “fixed” mode, but then can be disconnected when deploying the unit.

There are a number of companies who are developing and marketing turnkey command, control, and communications vehicles that include an audio baseband switch as well as a variety of other capabilities. The interoperability capabilities integrated into these vehicles are typically the audio baseband switch technologies described in this section.

There are a number of different types of audio baseband switches, ranging in complexity and cost from two-channel repeaters to large-scale switches with hundreds and even thousands of interfaces. Various types of these switches are listed below:

- Two-channel crossband repeaters – The simplest devices are two channel repeaters. These devices are slightly different than depicted in Figure 3-4, as an audio backplane switch is not required to distribute audio among just two interfaces. We include two-channel repeaters in this discussion because they perform a function similar to more sophisticated switches. These products are generally not new to the market and are in use in many modern radio systems. Repeaters have typically been configured to transmit and receive on frequencies in the same band (functioning as in-band repeaters) for range extension and in-building coverage. Repeaters in the amateur radio service have been commonly configured as crossband repeaters.[17] A list of repeater products is included in Table 3-4.

[17] Caution should be exercised when selecting a repeater to extend or crossband frequencies together. Some older repeaters and or systems may use older technology repeaters that crossband internally through non audio base band circuitry. These type of systems require more detailed engineering analysis.

Table 3-4: Crossband/In-band Repeaters

<table>
<tr><th>Manufacturer</th><th>Product</th><th>Frequency Range (MHz)</th><th>Channel Availability</th><th>Analog/Digital</th></tr>
<tr><td>BK Radio/Relm</td><td>DRV50</td><td>136-174 403-490</td><td>512</td><td>A/D*</td></tr>
<tr><td rowspan="3">Daniels Repeater®</td><td>AN 400</td><td rowspan="3">30-50 132-174 406-470 806-869 896-960</td><td rowspan="3">16</td><td rowspan="3">A*</td></tr>
<tr><td>AN 410</td></tr>
<tr><td>AN 420</td></tr>
<tr><td rowspan="2">EF Johnson</td><td>2601</td><td>132-178</td><td>Single</td><td rowspan="2">A/D*</td></tr>
<tr><td>5600</td><td>Unavailable</td><td>256</td></tr>
<tr><td rowspan="2">Futurecom Systems</td><td>Mobexcom II</td><td rowspan="2">136-174 403-430 450-470 470-512 806-825/851-870 896-902/935-942</td><td rowspan="2">64</td><td rowspan="2">A/D</td></tr>
<tr><td>Mobexcom†</td></tr>
<tr><td>Icom America</td><td>PAN F320S</td><td>146-174</td><td>Unavailable</td><td>A</td></tr>
<tr><td>Icom America</td><td>PAN F420S</td><td>450-470</td><td>Unavailable</td><td>A</td></tr>
<tr><td>KR Nida Corp.</td><td>PTR-200</td><td>134-174 403-475</td><td>114</td><td>A/D</td></tr>
<tr><td rowspan="3">M/A-COM</td><td>MASTR III 800</td><td>806-825 851-870</td><td rowspan="3">16</td><td rowspan="3">A/D</td></tr>
<tr><td>MASTR III VHF</td><td>136-174</td></tr>
<tr><td>MASTR III UHF</td><td>403-512</td></tr>
<tr><td rowspan="3">Motorola</td><td>GR 300</td><td>136-174, 403-520</td><td rowspan="3">Radio Dependent</td><td rowspan="3">A/D*</td></tr>
<tr><td>GR 400</td><td rowspan="2">Radio Dependent</td></tr>
<tr><td>GR 500</td></tr>
<tr><td>Panther Electronics</td><td>Millennium</td><td>136-172 406-520</td><td>4 or 32</td><td>A/D</td></tr>
<tr><td>Plettac Mobile Radio</td><td>MT 510 BP</td><td>66-520</td><td>99</td><td>A</td></tr>
<tr><td>Relm Wireless</td><td>SRV50</td><td>30-50 72-88 135-520 746-794 806-870</td><td>255</td><td>A</td></tr>
<tr><td rowspan="3">Tait Electronics</td><td>T800 100W</td><td>136-174 220-285 400-520 800-960</td><td rowspan="3">128</td><td rowspan="3">A</td></tr>
<tr><td>T800 50W</td><td rowspan="2">66-88 136-174 330-380 400-520 800-960</td></tr>
<tr><td>T800 25W</td></tr>
<tr><td rowspan="2">Transcrypt Int.</td><td>TR30-021</td><td rowspan="2">Radio Dependent</td><td rowspan="2">Radio Dependent</td><td rowspan="2">A/D*</td></tr>
<tr><td>TR30-022</td></tr>
<tr><td>Vertex</td><td>VXR-1000†</td><td>150-174 450-470</td><td>16</td><td>A</td></tr>
</table>

*-APCO Project 25 compatible/optional
†-vehicular repeater

More complex examples of audio baseband switches are referred to as interconnect systems. Interconnect systems typically use an audio backplane to distribute audio among multiple radio interfaces. Interconnect system architecture has evolved from the simple cross-band repeater that connects two radio channels together to systems capable of interconnecting multiple, diverse organizations, each using incompatible radios and frequencies. Many interconnect systems utilize software to control connections and to configure radios to provide a flexible interoperability solution. Many are also capable of simultaneously interconnecting multiple HF, VHF low band, VHF high band, UHF, 800 MHz, 900 MHz, trunking talk-groups, encrypted networks, cell phones, satellite phones, and the public telephone network. Unlike a repeater, an interconnect system is not a radio and contains no radio boards.[18] An interconnect system contains the circuitry that allows for the linking of audio paths between radios, cellular phones or commercial phone lines. This capability along with the ability to condition and manipulate the audio signal overcomes the unique signaling differences of the incompatible systems and proprietary equipment restrictions. Interconnect systems can be further broken down in to subcategories as follows:

- Programmable Switching Devices – special purpose circuit switches capable of interfacing to voice and data systems. Applications include HF/VHF/UHF to PSTN patching capability, ideally suited for centralized communication centers and tactical command centers that require circuit switch support. Such devices can typically support upwards of 14,000 ports (requires connection to communication system).
- Modular Interconnects – specifically designed as customizable fixed or transportable interconnect systems that provide user-adjustable parameters to overcome audio problems associated with crossbanding conventional and trunked radio systems (analog and digital). Intelligent interconnects are capable of linking two or more systems and may be configured to support PSTN cellular and satellite phone circuits along with fulfilling the role of a mini-switchboard (some models may come equipped with all required radio equipment).
- Portable Radio Interfaces – specifically designed to support short duration operations that require crossbanding of two or more radio systems. Interface cables are used to connect various portable radios, interface circuitry may provide limited adjustments for repeater and or trunked systems delay.
- Transportable Communication Consoles – self-contained unit (radios included) that has been specifically designed as a portable unit that is capable of crossbanding two or more radios together with minimum user adjustable parameters.
- Site Linking/Retransmission Units – equipment specifically designed to link repeater sites together (both audio and signaling information) and/or radio systems (only audio signals). Equipment may be scaleable and provide a transparent linking of systems that may be software controlled; varying degrees of user-adjustable parameters may exist depending upon the specific equipment being interconnected.
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[18] LINK*net*™ by Kaval Telecom Inc. is designed using an integrated transceiver and does not require an external audio source.

Table 3-5 lists interconnect systems available for use by public safety agencies.

Table 3-5: Interconnect Systems

Manufacturer	Product	Number of Radio Interfaces/Ports	Radio to Telco Patch
Programmable Switches			
Compunetix	CONTEX® 240	240	Yes
	CONTEX® 480	480	
	Mini-CONTEX®	120	
Penta Corp.	PCx	512	Yes
	MNx	32	
REDCOM Lab., Inc	Tactical Com Package (TCP)*	Unavailable	Yes
Modular Interconnects			
JPS Comm., Inc.	ACU-T	5	Yes
	ACU-1000	12/24	
	TRP-1000*†	12/24	
Kaval Telecom., Inc.	LINK*net*™[19]	7/32/64	No
M/A-COM	SkyGate®[20]	12	Yes
Portable Radio Interfaces			
C-AT	ICRI Gen II	5/10	Yes
	ICRI Gen III	5/10	Yes
Transportable Communication Consoles			
KR NIDA Corp.	INTEROP-9†	10	No
	NC-17R-RC200	3	
	NC-14-RC200	2	
	NC-11-RC200	2	
	NC-11-SVR-RC200	2	

[19] Wireless coverage extension platform that enables all wireless coverage extension requirements to include crossbanding to be met simultaneously. Capable of single or multi-channel configurations that cover a variety of services including cellular, PCS, SMR, ESMR, iDEN™, trunking and advanced messaging.
[20] The SkyGate is a multi-channel analog voice interface for the OpenSky digital network and part of the NetworkFirst Interoperability Solution.

Manufacturer	Product	Number of Radio Interfaces/Ports	Radio to Telco Patch
Site Linking/Retransmission Units			
JPS Comm., Inc.	RRU-100	2	No
IDA Corp.	Easy-Link Plus™‡	2	No
	Net-Link MP‡	6	
IDA Corp.	Net-Link‡	2	No
KR NIDA Corp.	RC-200	3	No
Motorola	LYRIX 2001[21]	2 (Back to back 2-way interface or 3-way radio patch)	No
SMARTLINK Radio Networks Inc.	SiteLink®[22]	15/31	Yes
	SMRLink®	8[23]	

* Transportable
† Includes radios
‡ Provides linking for conventional to conventional, conventional to LTR®, or LTR® to LTR®.

[21] Specifically designed to convert 4 wire mobile and portable radios to standard four wire audio.
[22] Utilizes spread spectrum technology to link two sites.
[23] May be expanded by adding additional 8 card expansion shelves.

Interoperability Example: Alexandria, Virginia (MIRS)

In the Washington, D.C., Metropolitan area, many agencies have overlapping jurisdiction and routinely face situations that require a response from multiple departments. For example, the U.S. Park Police patrols the George Washington Parkway, which runs through Alexandria; the Metro Transit Police, Washington Metro Area Transit Authority (WMATA), are responsible for the Metro Transit system, which also runs through Alexandria. However, there is no effective means for personnel in these different agencies to directly communicate using their own radio systems. Agencies in the area operate radio systems at different frequencies, such as VHF low-band, VHF high-band, UHF, and 800 MHz.

Under the AGILE[24] program, a system-to-system gateway including two ACU-1000 units was installed at the Alexandria Police Department. The gateway is a fixed-site permanent installation that provides connectivity among the radio systems of the APD and other agencies participating in this initiative.

Each participating agency system provides access to at least one repeater, through which coverage of the agency's jurisdiction is available (Figure 3-6). Transmissions originating from portable or mobile radios are received by the associated repeater and re-broadcast to all corresponding units. When activated, transmissions are received simultaneously at the Gateway Subsystem through a repeater, and then rebroadcast on the input frequencies of the other participating agencies repeaters that are interconnected through the ACU-1000. The agencies' repeater sites receive the transmission and re-broadcast to the individual radios of the respective agencies.

The antennas are mounted on the roof of APD's headquarters building. The antennas were selected and installed in order to ensure that the radios interfaced to the ACU-1000 can communicate with select repeaters of each participating agency. In this way, any radio within the coverage area of its own land mobile radio system can communicate with the radio systems of the other participating agencies via the Gateway Subsystem.

The radios and ACU-1000 are mounted in equipment racks located in the Equipment Room of the APD Dispatch Center located at APD headquarters. The radios are programmed with frequencies licensed to the participating agencies. Typically, the radios are set to a default channel that a participating agency designates for inter-agency communications. Radio channels may be switched manually as required to transmit and receive on a different frequency channel, or to accommodate a different participating agency. For example, an 800 MHz radio (currently programmed to interface with APD) provides immediate expansion to accommodate additional participating agencies with 800 MHz radio systems and a repeater within coverage range of the Gateway Subsystem.

Connections can also include telephones. Connections can be made between two or more systems, so that in addition to two-way connections between radios, the Gateway Subsystem can simultaneously connect all interfaces (radios and telephone) to provide a conference call capability that can be used during multi-jurisdictional incidents.

[24] Additional information on the AGILE program is available at www.agileprogram.org.

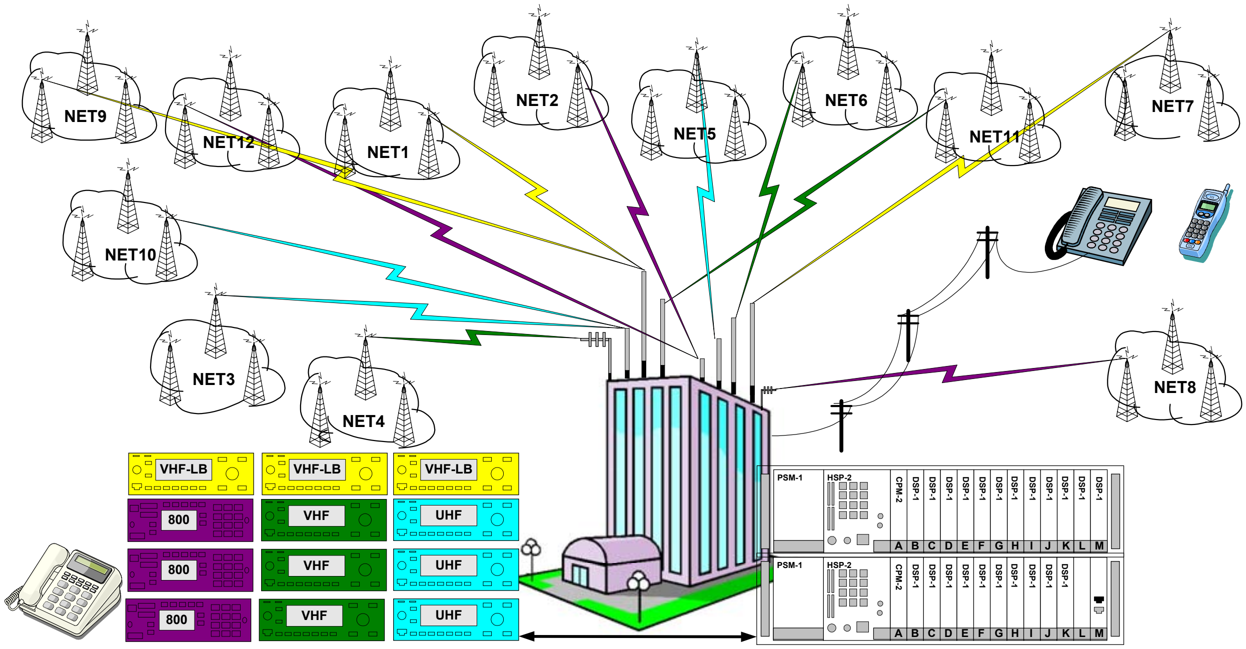

Figure 3-6: Fixed Site System-to-System Gateway

Interoperability Example: Lake Superior Integrated Border Enforcement Team (ICRI)

The Integrated Border Enforcement Teams (IBETs) are an integrated approach among U.S. and Canadian law enforcement agencies to address border issues. For example, the Lake Superior IBET conducted a tactical operation in late February, 2003. The operation was conducted on and around Drummond Island (Michigan) over a frozen Lake Huron. The object of the operation was to stop contraband and illegal aliens from crossings the U.S.-Canadian border in both directions.

Photo provided courtesy of U.S. Coast Guard

The ICRI was placed in and operated from a U.S. Border Patrol "SnowCat" that was deployed on the frozen lake. During the operation, the ICRI provided a vital link between checkpoints on the ice and the airborne and mobile ground units. The ICRI allowed for the cross-connection of a talk around channel of the Michigan State Police's 800MHz radio system to a common VHF frequency shared by U.S. Coast Guard, U.S. Custom, U.S. Immigration and Naturalization Service and U.S. Border Patrol to two independent UHF nets operated by the Royal Canadian Mounted Police and the Ontario Provincial Police.

Interoperability Example: World Trade Center (Redcom IGX Switch)

Shortly after the terrorist attack on the World Trade Center, the New York State Technology Enterprise Corporation (NYSTEC) was contacted by representatives from New York State Emergency Management Office (SEMO) and asked to stand at the ready to help support essential interagency communications needs. NYSTEC responded by mobilizing and deploying their Deployable Advanced Communications Environment (DACE) in conjunction with the NY Army National Guard. A Colonel in charge of Guard communications was deployed and assigned to NYSTEC, and the DACE was set up at Valhalla National Armory.

The DACE includes a Tactical Communications Package (TCP) manufactured by Redcom Laboratories. The TCP provides from 8 to 256 user-programmable keys for direct access to local phone lines, trunks, radio channels, conferences and special services (Figure 3-7).

The TCP was activated to monitor all public safety channels operating within lower Manhattan. This allowed the NY Army National Guard to keep abreast of all public safety issues being broadcasted in real-time. Historically the Guard has their own military communication systems that are not compatible with those of the public safety. The TCP allowed the NY Army National Guard to monitor the public safety bands. The military communications equipment was also installed in the DACE, but they were never connected together. While the TCP allows for this, the circumstances of the emergency were such that the National Guard monitored the public safety channels and broadcast information over their own military channels as needed to provide support during the recovery efforts at the WTC. Because of its advanced communication capability, the DACE has been turned over to the New York State Police as a vital resource to help establish or restore temporary critical communication during a crisis or emergency situation.

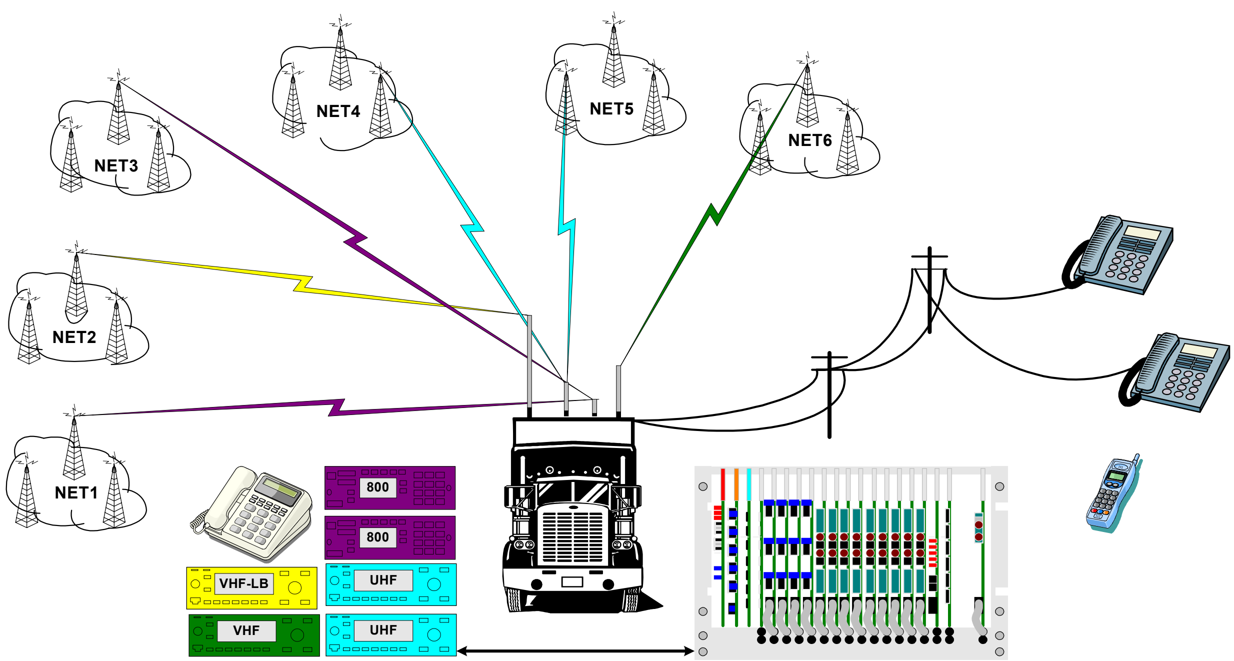

Figure 3-7: Mobile Interoperability System (Circuit Switch Based)

3.3.3 Multi-System Controllers

Another approach to achieving interoperability that has emerged in recent years is the multi-system controller. Through the use of interfaces and gateways, controlled by sophisticated computer operated network controllers, compatible stand-alone system are linked (patched) together to create one large system, which appears seamless to the user. OpenSky®, SMARTNET™/SmartZone® and Multi-Net® are examples of such systems. These systems allow for the linking (patching) of multiple subsystems together and now can span across large metropolitan areas or even entire States or regions. When connecting among compatible systems, these controllers can pass through not only the audio but also the control signaling as well, so that for trunked systems, trunking and talk group functionality can be created across systems. For incompatible systems, however, interoperability is achieved only by retransmitting baseband audio, much like the devices described in Section 3.3.2.

While system such as OpenSky®, SMARTNET/SmartZone® and Multi-Net® do provide a high level of interoperability they are more expensive than audio baseband devices and may take significantly longer to build-out.

3.4 VoIP

Interoperability using Voice over Internet Protocol (VoIP) refers to the transmission of voice data over a packet network using some type of Internet Protocol (IP) enabled gateway device to distribute digital audio among interconnected networks. Within the gateway, IPs are used to route IP packets (with voice & push to talk information) to selected recipient networks.

VoIP technology is being incorporated into various approaches to interoperability. For example, vendors are moving to IP-based systems as the basis for large shared systems. But VoIP is not unique to shared systems; products have been developed to interface system-to-system gateways using a VoIP link. VoIP is used today as an enabling technology that provides system architecture flexibility and exploits digital network infrastructure to implement different interoperability strategies. Thus, we do not include VoIP as a separate product or strategy. Instead, we recognize that VoIP technology is rapidly being incorporated into products that are part of the taxonomy definition shown in Figure 3-1.

VoIP is also enabling a whole new category of interoperability solutions that we refer to as network based architectures. Network based architectures fit the general category of system-to-system gateways, but with a network backbone rather than a switch used to link between radio systems. The network based architecture provides greater flexibility and scalability over existing switches. Technology is rapidly evolving in this area but there are not yet commercially available products in this category.

As noted in the discussion of products such as Open Sky®, SMARTNETᴹ/SmartZone® and Multi-Net®, VoIP technology is being employed within public safety communication products. While VoIP is used extensively as an enabling technology *within* some of these product architectures, standards have not been adopted for the exchange of VoIP data *among* Public Safety products. Although various approaches have been offered for adoption as a standard, interoperation (the exchange of voice data) among these devices via VoIP data is not generally available today. Current IP standards allow VoIP to be implemented in various ways within the standards themselves. Many implementers have taken standard IP protocols originally designed for data and modified (optimized) them for VoIP specific performance enhancement.

This "proprietary" use of VoIP technology inherently creates incompatibility among versions of the protocol that have been "tweaked" for specific performance advantages. For example, EF Johnson and Motorola both have radio systems that rely on optimized TCP/IP protocol within their closed network infrastructures. Yet, they adapt to a Project 25 or traditional wireless (air) interface for radio wave interconnection, ensuring compatibility between radio subscriber units. Telex/Vega manufactures a VoIP crosspatch panel that uses TCP/IP multicast protocols as the basis for their implementation. Catalyst and JPS use both UDP/IP for voice data, and TCP/IP for more reliable radio signaling data. This type of VoIP implementation is transparent, and immaterial, to the end user at a subscriber unit level.

A standards-based interface, such as the pending Project 25 ISSI interface may allow for VoIP interconnections between systems produced by competing manufacturers. As a result, use of VoIP protocols, as an enabling technology does not mean that the products are interoperable. VoIP may also make sense as a product enabling technology, not a strategy.

4 CROSS REFERENCE OF INTEROPERABILITY PRODUCTS BY FREQUENCY BAND

The intent of this section is to provide an easy to use cross-reference guide to crossband products. Table 4-1 lists the majority[25] of interoperability products referenced in Section 3 that are currently available to public safety. Table 4-1 lists the item by manufacture, method, product and type and then displays frequencies and conventions supported. The following guidelines may be helpful in determining which product would best meet each individual agencies requirements.

- Intended purpose (provide dispatchers patch capability; emergency response interoperability; range extension etc.).
- Frequency/bands to be linked.
- Type of radio systems to be linked: conventional, multicast, simulcast and or trunked.
- Number of users that require interoperability.

Table 4-1: Cross Reference of Interoperability Products

Manufacture	Method	Product	Type	Frequency and Conventions Supported						
				HF	VHF LB	VHF HB	UHF	800 MHz	Conven-tional	Trunked
Thales Communications Inc.	Multi-band	MBITR (AN/PRC 148)	Radio (Portable)		X	X	X		X	
Harris RF Communications	Multi-band	RF-5800V Falcon®	Radio (Mobile)		X	X			X	
Harris RF Communications	Multi-band	RF-5800M Falcon®	Radio (Mobile)		X	X	X		X	
Wulfsberg Electronics	Multi-band	Flexcomm™ II RT-5000	Radio (Aviation)	X	X	X	X	X	X	X
Vertex	Dual-band	FTH-2070	Radio (Portable)			X	X		X	*
Vertex	Dual-band	VX-4000	Radio (Mobile)		X	X	X		X	*
Kenwood Communications Inc.	Dual-band	TK-790/890(H)	Radio (Mobile)			X	X		X	X

[25] See C.3 Missed Product Disclaimer

Manufacture	Method	Product	Type	Frequency and Conventions Supported						
				HF	VHF LB	VHF HB	UHF	800 MHz	Conven-tional	Trunked
Communications Applied Technology	Interconnect	ICRI™ Gen II	Multiple cross-band	X	X	X	X	X	X	X
		ICRI™ Gen III	Multiple cross-band	X	X	X	X	X	X	X
Compunetix Communications Systems		CONTEX® 240	Patch	X	X	X	X	X	X	X
		CONTEX® 480	Patch	X	X	X	X	X	X	X
		Mini-CONTEX®	Patch	X	X	X	X	X	X	X
Penta Corp.		PCx	Patch	X	X	X	X	X	X	X
		MNx	Patch	X	X	X	X	X	X	X
REDCOM Lab., Inc.		Tactical Com Package (TCP)	Multiple cross-band	X	X	X	X	X	X	X
JPS Communications Inc.		ACU-1000	Multiple cross-band	X	X	X	X	X	X	X
		TRP-1000	Multiple cross-band	X	X	X	X	X	X	X
		RRU-100	Cross-band	X	X	X	X	X	X	X
IDA Corporation		Net-Link MP	Multiple in-band					X		X
		Net-Link	Multiple in-band					X		X
		Easy-Link Plus™	In-band					X		X
KR NIDA Corp.		INTEROP-9	Multiple cross-band	X	X	X	X	X	X	X
		NC-17R-RC200	Tri-band	X	X	X	X	X	X	X
		NC-14-RC200	Cross-band	X	X	X	X	X	X	X
		NC-11-RC200	Cross-band	X	X	X	X	X	X	X
		NC-11-SVR-RC200	Cross-band	X	X	X	X	X	X	X
		RC-200	Tri-band	X	X	X	X	X	X	X
Kaval Telecom Technologies Inc.		LINK*net*™	Multi cross-band	X	X	X	X	X	X	X
M/A-COM Wireless Systems		SkyGate®[26]	Multi cross-band	X	X	X	X	X	X	X
Motorola		LYRIX 2001	Tri-band	X	X	X	X	X	X	X
		SmartZone™[27]	Multi cross-band	X	X	X	X	X	X	X
SmartLink Development Network Corp.		SiteLink®	Multiple cross-band	X	X	X	X	X	X	X
		SMRLink®	Multiple cross-band	X	X	X	X	X	X	X

[26] The SkyGate is a multi-channel analog voice interface for the OpenSky digital network and part of the NetworkFirst Interoperability Solution.
[27] The SmartZone is primary designed to link trunking systems, but can be used to link conventional analog systems

Manufacture	Method	Product	Type	Frequency and Conventions Supported						
				HF	VHF LB	VHF HB	UHF	800 MHz	Conven-tional	Trunked
BK Radio/Relm	Repeater	DRV50	In-band			X	X		X	
Daniels Electronics Ltd.		AN 400	Cross-band	X	X	X	X	X	X	X
		AN 410	Cross-band	X	X	X	X	X	X	X
		AN-420	Cross-band	X	X	X	X	X	X	X
EF Johnson		2601	In-band			X				
		5600	Cross-band			X	X		X	X
Futurecom Systems		Mobexcom II	Cross-band			X	X	X	X	X
		Mobexcom	Cross-band			X	X	X	X	X
Icom America Inc.		PAN F320S	Cross-band			X			X	
		PAN F420S	Cross-band				X		X	
KR NIDA Communications		PTR 200	Tri-band			X	X		X	
M/A-COM Wireless Systems		MASTR III 800	Cross-band					X	X	X
		MASTR III VHF	Cross-band			X			X	X
		MASTR III UHF	Cross-band				X		X	X
Motorola		GR 300[28]	Cross-band			X	X		X	X
		GR 400	Cross-band			X	X		X	X
		GR 500	Cross-band			X	X		X	X
Panther Electronics		Millennium	In-band			X	X		X	
Plettac Mobile Radio GmbH		MT 510 BP	Cross-band		X	X	X		X	
Relm Wireless Corp.		SRV50	Cross-band		X	X	X	X	X	
Tait Radio Communications		T800 100W	Cross-band			X	X	X	X	
		T800 50W	Cross-band		X	X	X	X	X	
		T800 25W	Cross-band		X	X	X	X	X	
Transcrypt Int.		TR30-021	Cross-band		X	X	X		X	X
		TR30-022	Tri-band	X	X	X	X	X	X	X
Vertex Standard		VXR-1000	Cross-band			X	X		X	

[28] Desktop Repeater

Manufacture	Method	Product	Type	Frequency and Conventions Supported: HF	VHF LB	VHF HB	UHF	800 MHz	Conven-tional	Trunked
Avtec Inc.	Console/Patch	DSPATCH 32	Patch	X	X	X	X	X	X	X
		DSPatch	Patch	X	X	X	X	X	X	X
		DSPatchNET	Patch	X	X	X	X	X	X	X
Baker Integrated Tech.		DISPATCHWorks 7750	Patch	X	X	X	X	X	X	X
Compunetix Inc		CONTEX® 60T	Patch	X	X	X	X	X	X	X
		CONTEX® Mini T	Patch	X	X	X	X	X	X	X
		CONTEX® 500T	Patch	X	X	X	X	X	X	X
		CONTEX® 1000T	Patch	X	X	X	X	X	X	X
		CONTEX® 2000T	Patch	X	X	X	X	X	X	X
Cyfas Systems Limited		CX2000-NT	Patch	X	X	X	X	X	X	X
		C10	Patch	X	X	X	X	X	X	X
GAI-Tronics® Corp		Comtegra Console	Patch	X	X	X	X	X	X	X
		CommandPlus Console	Patch	X	X	X	X	X	X	X
General Devices		NetManager™	Patch	X	X	X	X	X	X	X
M/A-COM Wireless Systems		C3Maestro	Patch	X	X	X	X	X	X	X
Moducom		Ultra--Com 2000	Patch	X	X	X	X	X	X	X
Motorola Inc.		CENTRACOM Elite	Patch	X	X	X	X	X	X	X
Orbacom Systems		TDM 25	Patch	X	X	X	X	X	X	X
		TDM Modular	Patch	X	X	X	X	X	X	X
		TDM Series CRT	Patch	X	X	X	X	X	X	X
REDCOM Lab. Inc.		DCCX	Patch	X	X	X	X	X	X	X
Safetran Systems		DTX	Patch	X	X	X	X	X	X	X
Telex/Vega[29]		C-6124	Patch	X	X	X	X	X	X	X
		C-6200	Patch	X	X	X	X	X	X	X
Zetron Inc.		M4010	Patch	X	X	X	X	X	X	X
		M4020	Patch	X	X	X	X	X	X	X
		M4048	Patch	X	X	X	X	X	X	X
		S4000	Patch	X	X	X	X	X	X	X
		Acom Adv. Comm Sys	Patch	X	X	X	X	X	X	X

* Information Unavailable

[29] VoIP Radio/Telephone Crosspatch Control

5 CROSS REFERENCE OF INTEROPERABILITY PRODUCT CHARACTERISTICS

The intent of this section is to provide an easy to use product characteristic guide for comparison purpose. Table 5-1 lists products,[30] that are currently available to public safety agencies, and then identifies main characteristics of each product to include a relative cost rating. The relative cost is based on the cost of the actual end item equipment. The relative cost does not does not take into consideration the additional cost that may be required to engineer or install the equipment or any additional equipment that may be required such as radios, antennas, lightning arrestors, cabling and equipment racks. The following guidelines may be helpful in determining which product would best meet each individual agency's requirements.

- The scenarios requiring interoperability (incident response, mutual aid, task force operations).
- Number of agencies and channels that require interoperability.
- Maximum number simultaneous connections.
- Manufacture of radio systems: Motorola, EF Johnson, M/A-COM etc.
- Whether the radio systems are conventional or trunked, and the frequency bands in which the interoperability product works (see Table 4-1).
- Whether a phone patch is required.
- Whether the link/connection is permanent or temporary.
- Whether the equipment must be transportable.
- Level of control, centralized or remote.

[30] See C.3 Missed Product Disclaimer.

Table 5-1: Product Characteristics

Product Name	Characteristics																				
	Integrated Transceiver	Analog/Digital A/D	External Radios Included	External Radios Required	Analog Base-band Signaling	Other External Signaling Source Required	Compatible w/Multiple Signaling Formats	User Adjustable Parameters	Software Controlled (Local)	Software Controlled (Remote)	Software Programmable	Fixed Site Application	Deployable /Mobile Application	Man-portable	Modular Design or Customizable	Expandable	System Restrictive[31]	Max Number of Simultaneous Nets	Ports	Cost [32] High /Medium/Lows H/M/L	Non Radio Interfaces
ICRI™ Gen II		A/D		X	X			X					X	X		X		1	6[33]	L	X
ICRI™ Gen III		A/D		X	X			X					X	X		X		2	6[34]	L	X
CONTEX® 240				X	X		X	X	X	X	X	X			X	X		120	240	H	X
CONTEX® 480				X	X		X	X	X	X	X	X			X	X		240	480	H	X
Mini-CONTEX®				X	X		X	X	X	X	X	X			X	X		60	120	M	X
PCx		A/D		X	X		X	X	X	X	X	X			X	X		*	512	H	X
MNx		A/D		X	X		X	X	X	X	X	X			X	X		*	32	H	X
Tactical Com Package (TCP)		A/D		X	X		X	X	X	X	X		X		X	X		*	*	M	X
ACU-1000		A/D		X	X			X	X	X	X	X			X	X		8	12	L	X
TRP-1000		A/D	X		X			X	X	X	X		X		X	X		8	12	M	X
RRU-100		A/D		X	X							X						1	2	L	
Net-Link MP		A		X	X				X	X	X	X					X	3	6	L	
Net-Link		A		X	X				X	X	X	X					X	3	6	L	
Easy-Link Plus™		A		X	X				X	X	X	X						1	2	L	
INTEROP-9		A/D	X		X			X			X		X					1	10	M	
NC-17R-RC200		A/D		X	X			X			X		X	X				1	3	L	
NC-14-RC200		A/D		X	X			X			X		X	X				1	3	L	

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[31] Device is designed to be used as part of a proprietary system or network and not as a generic device.
[32] Cost is derived from a relative comparison of other devices capable of cross-patching radio nets (does not include engineering cost, site installation cost, and or additional equipment that may be required such as radios, antennas, grounding equipment interface cables etc.).
[33] One port used exclusively for teleco interfaces.
[34] One port used exclusively for teleco interfaces.

Product Name	Integrated Transceiver	Analog/Digital A/D	External Radios Included	External Radios Required	Analog Base-band Signaling	Other External Signaling Source Required	Compatible w/Multiple Signaling Formats	User Adjustable Parameters	Software Controlled (Local)	Software Controlled (Remote)	Software Programmable	Fixed Site Application	Deployable /Mobile Application	Man-portable	Modular Design or Customizable	Expandable	System Restrictive[31]	Max Number of Simultaneous Nets	Ports	Cost [32] High /Medium/Lows H/M/L	Non Radio Interfaces
	Characteristics																				
NC-11-RC200		A/D		X	X			X			X		X	X				1	2	L	
NC-11-SVR-RC200		A/D		X	X			X			X		X	X				1	2	L	
RC-200		A/D		X	X			X			X	X						1	3	L	
LINK*net*™	X	A/D					X	X	X	X	X	X			X	X		†	64	M	X
SkyGate®		A/D			X	X	X	X	X	X	X	X			X	X	X	†	12	M	X
LYRIX 2001		A/D		X	X			X				X	X	X	X	X	X	1	1	L	X
SmartZone™		A/D			X	X	X	X	X	X	X	X			X	X	X	*	*	M	X
SiteLink®		A/D		X	*		X	X	X	X	X	X			X	X		*	*	H	X
SMRLink®		A/D		X	*		X	X	X	X	X	X			X	X		*	*	H	X
DRV50	X	D			*			*			*	X						1	2	L	
AN 400	X	A/D			X			X			*	X			X	X		1	2	L	
AN 410	X	A/D			X			X			*	X			X	X		1	2	L	
AN-420	X	A/D			X			X			*	X			X	X		1	2	L	
2601	X	A/D			X			X			X	X				X	X	1	1	L	
5600	X	A/D			X			X			X	X				X	X	1	1	L	
Mobexcom II		A/D		X	*			*			X		X					1	2	L	
Mobexcom		A/D		X	*			*			X		X					1	2	L	
PAN F320S	X	A			X			X			*	X						1	1	L	
PAN F420S	X	A			X			X			*	X						1	1	L	
PTR 200		A/D	X		X			X			X		X					1	3	L	
MASTR III 800	X	A/D			X			X		X	X	X				X	X	1	1	L	
MASTR III VHF	X	A/D			X			X		X	X	X				X	X	1	1	L	

Product Name	Characteristics																				
	Integrated Transceiver	Analog/Digital A/D	External Radios Included	External Radios Required	Analog Base-band Signaling	Other External Signaling Source Required	Compatible w/Multiple Signaling Formats	User Adjustable Parameters	Software Controlled (Local)	Software Controlled (Remote)	Software Programmable	Fixed Site Application	Deployable /Mobile Application	Man-portable	Modular Design or Customizable	Expandable	System Restrictive[31]	Max Number of Simultaneous Nets	Ports	Cost [32] High /Medium/Lows H/M/L	Non Radio Interfaces
MASTR III UHF	X	A/D			X			X		X	X	X				X	X	1	1	L	
Millennium	X	A/D			X			X			X	X						1	2	L	
GR 300		A/D		X				X				X				X	X	1	*	L	X
GR 400		A/D		X				X				X				X	X	1	*	L	X
GR 500		A/D		X				X				X				X	X	1	*	L	X
MT 510 BP	X	A			X			X			X	X				X		1	2	L	
SRV50	X	A			X			X		X	X	X						1	2	L	
T800 100W	X	A			X			X		X	X	X						1	1	L	
T800 50W	X	A			X			X		X	X	X						1	1	L	
T800 25W	X	A			X			X		X	X	X						1	1	L	
TR30-021		A/D		X	X			X				X	X	X				1	2	L	
TR30-022		A/D		X	X			X				X	X	X				1	3	L	
VXR-1000		A		X	X			X					X					1	2	L	
DSPATCH 32		A/D		X	X		X	X	X	X	X	X			X	X		150	32	H	X
DSPatch		A/D		X	X		X	X	X	X	X	X			X	X		640	2048	H	X
DSPatchNET		A/D		X	X		X	X	X	X	X	X			X	X		2560	4096	H	X
DISPATCHWorks		A/D		X	X		X	X	X		X	X			X	X		*	96	H	X
CONTEX® 60T		A/D		X	X		X	X	X		X	X			X	X		30	60	H	X
CONTEX® Mini T		A/D		X	X		X	X	X		X	X			X	X		200	400	H	X
CONTEX® 500T		A/D		X	X		X	X	X		X	X			X	X		300	600	H	X
CONTEX® 1000T		A/D		X	X		X	X	X		X	X			X	X		960	1920	H	X
CONTEX® 2000T		A/D		X	X		X	X	X		X	X			X	X		1200	2400	H	X

Product Name	Characteristics																			
	Integrated Transceiver	Analog/Digital A/D	External Radios Included	External Radios Required	Analog Base-band Signaling	Other External Signaling Source Required	Compatible w/Multiple Signaling Formats	User Adjustable Parameters	Software Controlled (Local)	Software Controlled (Remote)	Software Programmable	Fixed Site Application	Deployable /Mobile Application	Man-portable	Modular Design or Customizable	Expandable	System Restrictive[31]	Max Number of Simultaneous Nets	Ports	Cost [32] High /Medium/Lows H/M/L	Non Radio Interfaces
CX2000-NT		A/D		X	X		X	X	X	X	X	X			X	X		*	125	H	X
C10		A/D		X	X		X	X	X			X			X	X		*	10	H	X
Comtegra Console		A/D		X	X		X	X	X		X	X			X	X		*	192	H	X
CommandPlus Console		A/D		X	X		X	X	X		X	X			X	X		12	192	H	X
NetManager™		A/D		X	X		X	X	X		X	X			X	X		12	*	H	X
C3Maestro		A/D		X	X		X	X	X		X	X			X	X	X	*	112	H	X
Ultra-Com 2000		A/D		X	X		X	X	X		X	X			X	X		*	247	H	X
CENTRACOM Elite		A/D		X	X		X	X	X		X	X			X	X	X	*	120	H	X
TDM 25		A/D		X	X		X	X	X		X	X			X	X		*	12	H	X
TDM Modular		A/D		X	X		X	X	X		X	X			X	X		*	120	H	X
TDM Series CRT		A/D		X	X		X	X	X		X	X			X	X		*	1000	H	X
DCCX		A/D		X	X		X	X	X		X	X			X	X		*	240	H	X
DTX		A/D		X	X		X	X	X		X	X			X	X		*	*	H	X
C-6124		A/D		X	X		X	X			X	X				X		1	24	M	X
C-6200		A/D		X	X		X	X			X	X				X		3	18	M	X
M4010		A/D		X	X		X	X			X		X		X	X		*	12	M	X
M4020		A/D		X	X		X	X	X		X	X			X	X		10	20	H	X
M4048		A/D		X	X		X	X	X		X	X			X	X		24	48	H	X
S4000		A/D		X	X		X	X	X		X	X			X	X		24	48	H	X
Acom Adv. Com Sys		A/D		X	X		X	X	X		X	X			X	X		*	1500	H	X

* Information Unavailable

† Dispatch console equipment dependent

A METHODOLOGY USED IN THE DEVELOPMENT OF THIS GUIDE

The methodology applied during the development of this guide to interoperability strategies and products is as follows. The first step was to define the requirement (Need for Interoperability) and then outline the current technologies (Interoperability Strategies) used to overcome incompatible radio systems/networks. Where possible several cases studies were cited to give a better understanding and provide information from a practitioner's aspect. The second step was to match and list commercially available equipment and hardware in loosely organized groups in an effort to provide a list of products that were similar in design. The intent of this list is to allow for initial matching of a product to a requirement, which can later be cross-referenced against Table 4-1 (frequencies and conventions) and Table 5-1 (product characteristics).

During development of this guide, it became necessary, due to the sheer volume of equipment available to regroup and move several items into different categories. Readers will find that while methods or approaches may differ some characteristics will overlap. In most cases, agencies will find that it is necessary to obtain technical assistance from a qualified communications expert that is both familiar with the agencies in question and their communication systems. In all cases, due to safety issues related to communication requirements of public safety, references should be obtained from equipment manufacturers and detailed plans should be developed when providing and implementing new capabilities.

B REFERENCES

B.1 Public Agencies

- Office of Justice Programs, US Office of Justice, Information Technology, http://www.ojp.usdoj.gov/
- National Institute of Justice (NIJ), Publications, http://www.ojp.usdoj.gov/nij/
- Wireless Communications and Interoperability Among State and Local Law Enforcement Agencies, NIJ, January 1998, http://www.ojp.usdoj.gov/nij/lawedocs.htm#1998
- AGILE Interoperability Strategies for Public Safety, Reports, http://www.nlectc.org/agile/
- National Law Enforcement & Corrections Technology Center, Virtual Library, http://www.nlectc.org/virlib/
- Public Safety Wireless Network (PSWN), Library, http://www.pswn.gov/

B.2 Private/Commercial Manufactures

- Avetec Inc., 4335 Augusta Highway, Gilbert, SC 29054, http://www.avtecinc.com/
- Baker Integrated Tech., 2195 N. Norcross Tucker Road, Norcross, Georgia 30071 http://www.dispatchworks.com
- BK Radio, 7100 Technology Drive, W. Melbourne, FL 32904, http://www.relm.com/
- Communication Applied Technology, 11250-14 Roger Bacon Dr., Reston VA 20190, http://www.c-at.com/
- Compunetix Communications Systems, 2420 Mosside Blvd., Monroeville, PA 15146, http://www.compunetix.com/
- Cyfas Systems Limited, 11 Albone Way, Biggleswade Beds, SG18 8BN, http://www.cyfas.co.uk/
- Daniels Electronics Ltd., 43 Erie St. Victoria, BC CANADA V8V 1P8, http://www.danelec.com/
- EF Johnson, 299 Johnson Avenue, Waseca, MN 56093, http://www.efjohnson.com/
- Futurecom Sys., (Simulcast Solutions) 18 Port Meadow Trail, Fairport, NY 14450, http://www.simulcastsolutions.com/
- GAI-Tronics Corp., 400 East Wyomissing Avenue, Mohnton, Pa 19540 http://www.gai-tronics.com/
- General Devices, 1000 River Street, Ridgefield, New Jersey 07657, http://www.general-devices.com/
- Harris RF Communications, 1680 University Ave., Rochester, New York 14610, http://www.rfcomm.harris.com/
- Icom America Inc., 2380-116th Ave NE, Bellevue, WA 98004, http://www.icomamerica.com/
- IDA Corp., 1345 Main Ave., Fargo, ND 58103,

http://www.idaco.com/
- JPS Communications Inc., 5800 Departure Dr. Raleigh, NC 27616, http://www.jps.com/
- Kaval Wireless Tech. Inc., 600 Cochrane Dr., 5th Floor, Markham, Ontario L3R 5K3, http://www.kaval.com/
- Kenwood Communications Corp., P.O. Box 22745 - Long Beach, CA 90801, http://www.kenwood.net/
- KR NIDA Communications, 2712 Foothill Blvd., Suite A, La Crescenta, CA. 91214, http://www.kaval.com/
- M/A-COM Wireless Systems, 3315 Old Forest Rd. Lynchburg, VA 24501, http://www.macom-wireless.com/
- Moducom, 13309 Saticoy St., No. Hollywood, CA 91605 http://www.moducom.com/
- Motorola Inc., 2501 San Pedro N.E. Suite 202, Albuquerque, NM 87110, http://www.motorola.com/
- Orbacom Systems, 1704 Taylors Ln., Cinnaminson, NJ 08077, http://www.orbacom.com/
- Panter Electronics, 4540 Lake Gentry Road, Bldg. 100, St. Cloud, Florida 34772, http://www.pantherelectronics.com/
- Penta Corp., 325 Edwards Ave., New Orleans, LA 70123, http://www.penta-corp.com/
- Plettac Mobile Radio GmbH, Würzburger Str. 150, D-90766 Fürth, Germany, http://www.plettac-mr.com/
- REDCOM Laboratory Inc., Victor, New York 14564, http://www.redcom.com/
- RELM Wireless Corp., 7100 Technology Drive, West Melbourne, FL 32904, http://www.relm.com/
- Safetran Systems, 10655 7th St., Rancho Cucamonga, California 91730, http://www.safetran.com/
- SMARTLINKS Radio Network Inc., 5 Brookside Drive, Wallingford, CT, 06492, http://www.smartlinklp.com/
- Tait Radio Communications., Unit 5, 158 Anderson Ave, Markham, Ontario L6E1A9, http://www.taitworld.com/
- Telex/Vega, 8601 East Cornhusker Highway, Lincoln, NE, 68507, http://www.vega-signaling.com/
- Thales Communications Inc., 22605 Gateway Center Dr., Clarksburg, MD 20871, http://www2.racalcomm.com/
- Transcrypt International, EFJ, Inc., 1232 22nd St. NW, Washington, DC 20037, http://www.transcrypt.com/contact.htm
- Vertex Standard, 10900 Walker Street, Cypress, CA 90630, http://www.yaesu.com/
- Wulfsberg Electronics, 6400 Wilkinson Drive, Prescott, AZ 86301, http://www.wulfsberg.com/
- Zetron Inc., PO Box 97004, Redmond WA 98073, http://www.zetron.com/

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