



Technical Solutions

Crossband Repeater

THIS CROSSBAND REPEATER ANALYSIS HIGHLIGHTS THE FOLLOWING

- Technical background, technical descriptions, and conceptual drawings
- Appropriate uses
- Advantages and disadvantages
- Costs
- Spectrum requirements
- Management issues
- Security and standards issues
- Implementations

THIS SOLUTION REQUIRES TRANSMIT AND RECEIVE AUDIO AND SQUELCH LOGIC CONTROL INPUTS AND OUTPUTS

- Typically, public safety agencies have access to a single radio system with its own frequencies, modulation scheme, bandwidth, encryption, and signalling. Each radio system base station or mobile unit can usually provide an audio interface. The audio interface serves to interconnect a base station or mobile radio in one radio system with a base station or mobile radio in another
- Each radio system typically assigns a mutual aid dispatch channel or talk group and a mutual aid tactical channel or talk group to support interoperable operation with other radio systems. To interoperate using a crossband repeater, each radio must have squelch logic control inputs and outputs. That is, the transmitter section of each radio must have a “Push-To-Talk” (PTT) logic input that inhibits reception while activating transmission across the radio path. Normally, users activate the PTT logic by pressing a button attached to a microphone. In turn, the receiver section of each radio can have a “Carrier-Operated Relay” (COR) or “Carrier-Operated Squelch” (COS) output that activates audio output from the receiver and can be used as the PTT logic signal into the other radio
- Ideally, each interconnected system is represented by a radio that has both PTT inputs and COR or COS outputs. Crossing audio leads and squelch logic leads between two radios with these capabilities allows disparate radio systems to interoperate. Few radios have manufacturer interfaces that provide PTT input and COR or COS output, however, voice activation (VOX) circuits are typically required to detect received audio and provide COR or COS squelch logic, and radio modifications are often required to access PTT squelch logic

THIS SOLUTION REQUIRES TRANSMIT AND RECEIVE AUDIO AND SQUELCH LOGIC CONTROL INPUTS AND OUTPUTS (CONTINUED)

- Some radios with no manufacturer audio interfaces must be modified to access transmit-and-receive audio. Transmit-and-receive audio levels can vary by message and by radio type. Sometimes audio levels can be adjusted manually or via program control. Otherwise, audio level control boards may be required between interconnected radios. Trunked radio systems may offer an additional interconnection challenge by requiring the participating radio system to pause for access to a talk group. Repeater hang times and trunked system talk permit tones may also cause undesirable oscillations of the keyed state of the interconnected radios
- Audio circuit impedances are different for transmit microphone audio input and speaker audio output. These impedance mismatches can be accommodated using transformer and resistor circuit combinations

INTEROPERABILITY BETWEEN SYSTEMS OPERATING IN DIFFERENT FREQUENCY BANDS CAN BE ACHIEVED THROUGH CROSSBAND REPEATING IN ONE OF FOUR WAYS

- Base station-base station interconnection
- Mobile radio-mobile radio interconnection
- Audio cross-connect switch
- Software-driven digital signal processor (DSP) device that mimics two or more radio systems

THE BASE STATION-BASE STATION CROSSBAND REPEATER IS TYPICALLY THE IDEAL BACK-TO-BACK RADIO SYSTEM SOLUTION

- Base station radios typically have 600 ohm balanced transmit-and-receive audio inputs and outputs, PTT squelch logic input, and COR or COS squelch logic output if a line interface module card is included
- The receive audio output from one base station can serve as the transmit audio input of a second base station and vice versa (using appropriate attenuation for level balancing)
- In turn, the COR or COS squelch logic output from one base station can serve as the PTT squelch logic input of a second base station
- It may be necessary to match logic levels for compatibility between base stations
- It may be necessary to provide separate audio-level controls

THIS IMPLEMENTATION ACHIEVES INTEROPERABILITY BY USING TWO MOBILE RADIOS IN A BACK-TO-BACK CONFIGURATION

- Mobile radios typically do not have 600 ohm balanced transmit-and-receive audio access nor COR or COS squelch logic output, but do have PTT logic inputs
- If transmit-and-receive audio is unavailable, radios can be modified by internal jumpers to access audio inputs and outputs to an auxiliary plug
- If PTT logic input is unavailable at an auxiliary plug, it can typically be accessed by modifying the microphone wiring that contains a PTT circuit
- Lack of COR or COS squelch logic output requires either a significant manufacturer modification of the radio or an external VOX circuit interface. Manufacturer modification of this type is rare because it is usually expensive and renders the radio unique in the system's radio fleet, limiting replacement options during critical missions
- When levels and impedances are matched, the receive audio output from one mobile radio can serve as the transmit audio input of a second mobile radio
- The receive audio output also drives the VOX circuit, which provides COR or COS squelch logic
- When properly configured, the VOX squelch logic output from one mobile radio can serve as the PTT squelch logic input of a second mobile radio
- It may be necessary to match logic levels for compatibility between mobile radios (current, voltage, impedance)
- It may be necessary to provide separate audio-level control (for proper balance of modulation, etc.)

THIS IMPLEMENTATION USES AN AUDIO CROSS-CONNECT SWITCH TO INTERCONNECT SEVERAL RADIO SYSTEMS

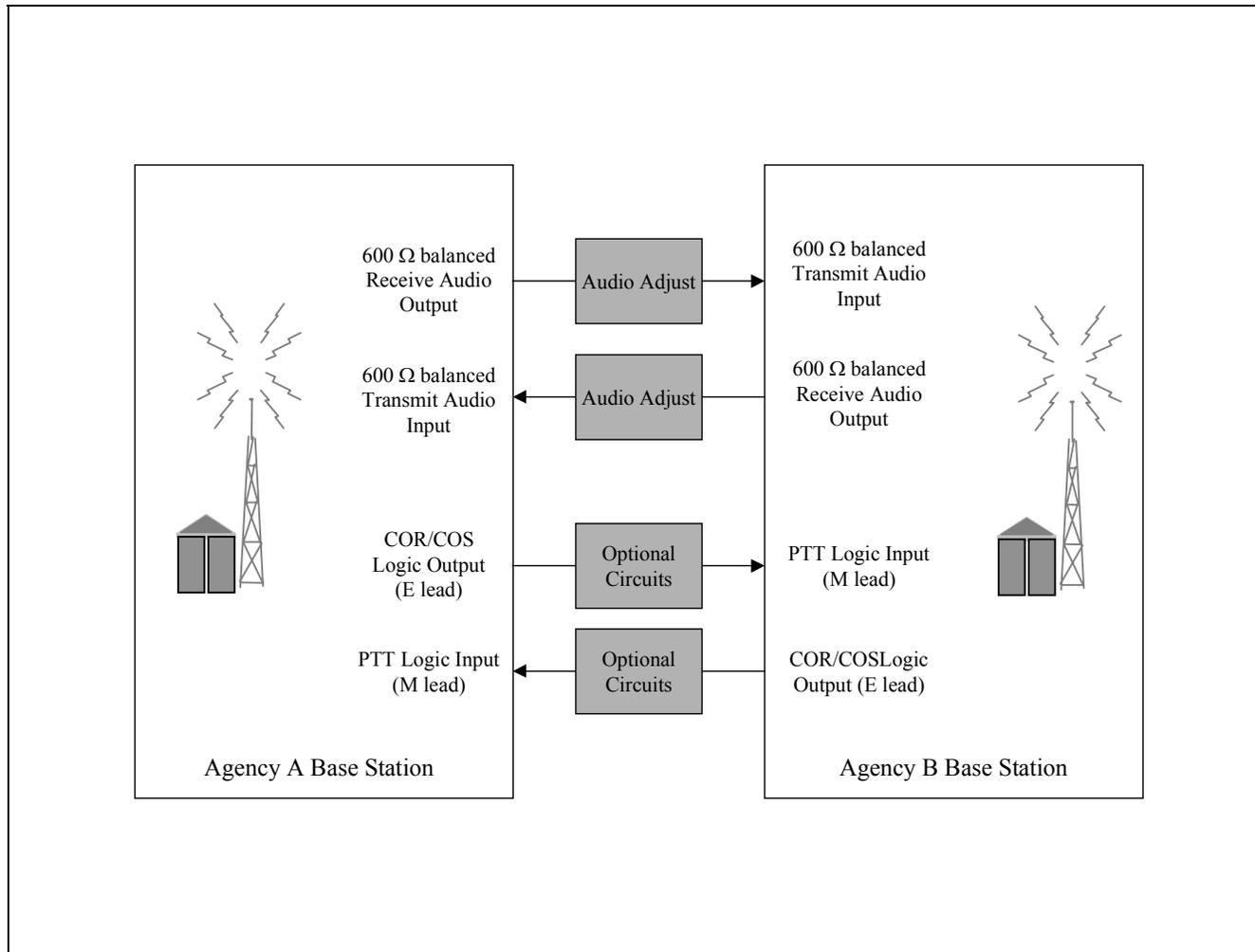
- Each radio system must provide a representative base station or mobile radio
- The audio cross-connect switch can manage and route audio levels, PTT and COR or COS squelch logic and VOX
- The switch is typically programmable and may be remotely configured

THE DIGITAL SIGNAL PROCESSOR (DSP) CROSSBAND REPEATER IS A DEVICE WITH MULTIPLE SOFTWARE-DRIVEN DSP CARDS THAT CAN MIMIC DIFFERENT RADIO SYSTEMS BY PROCESSING THE RADIO WAVEFORM DIRECTLY

- A DSP card is used for each radio system and is programmed via software to modulate and demodulate the radio system radio frequency (RF) signal
- The DSP can act as both the transmitter and the receiver sections of a radio, thereby recognizing both the transmit audio and the receive audio present on the radio system
- The device can connect two or more DSP cards and control squelch logic internally
- This type of interoperability is currently in its infancy (at the time of this report)

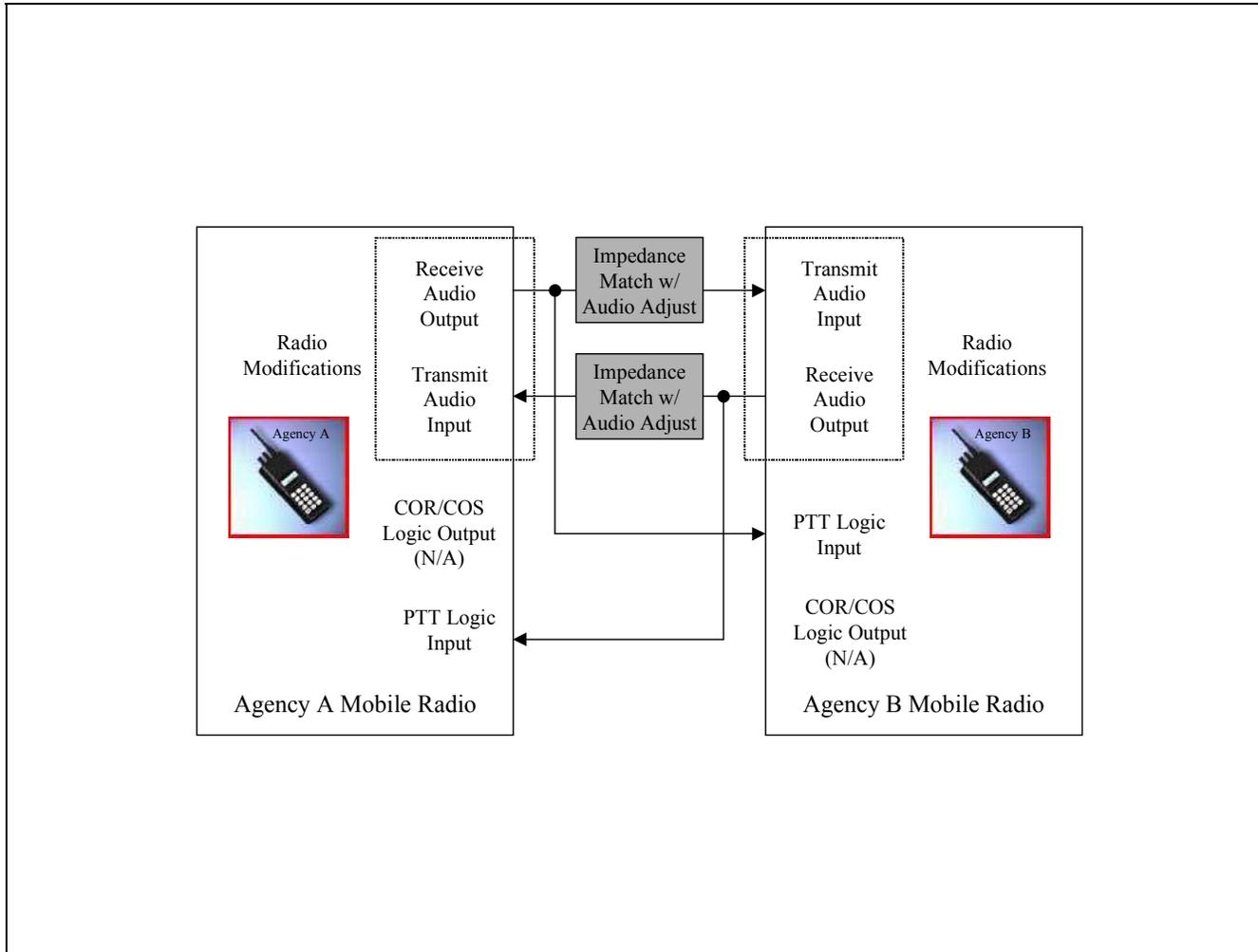
Crossband Repeater Solution...Conceptual Drawings...

THE DRAWING BELOW ILLUSTRATES THE CONCEPT OF A BASE STATION-BASE STATION CROSSBAND REPEATER WITH A LINE INTERFACE MODULE FOR 4 WIRE/E&M CONTROL

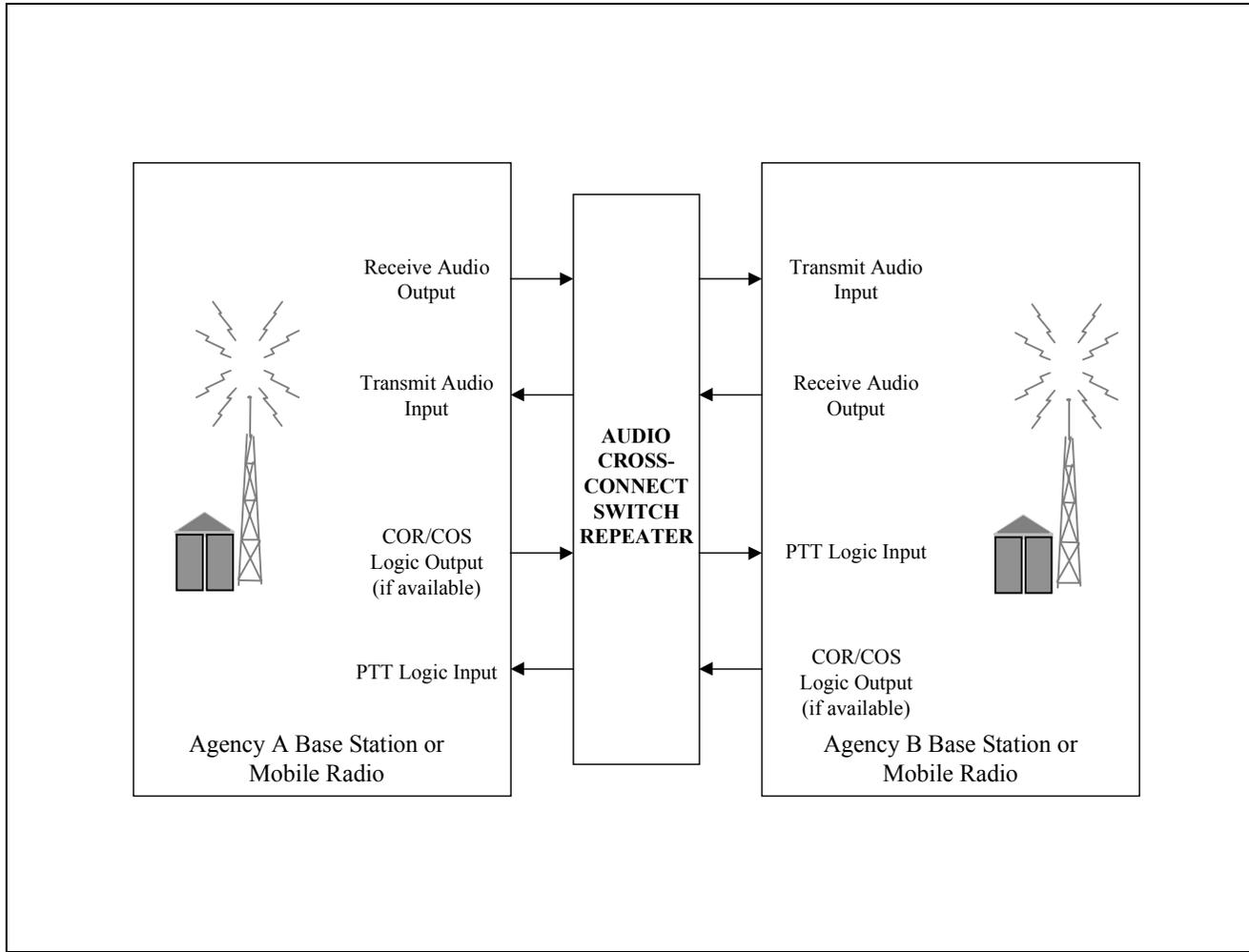


Crossband Repeater Solution...Conceptual Drawings...

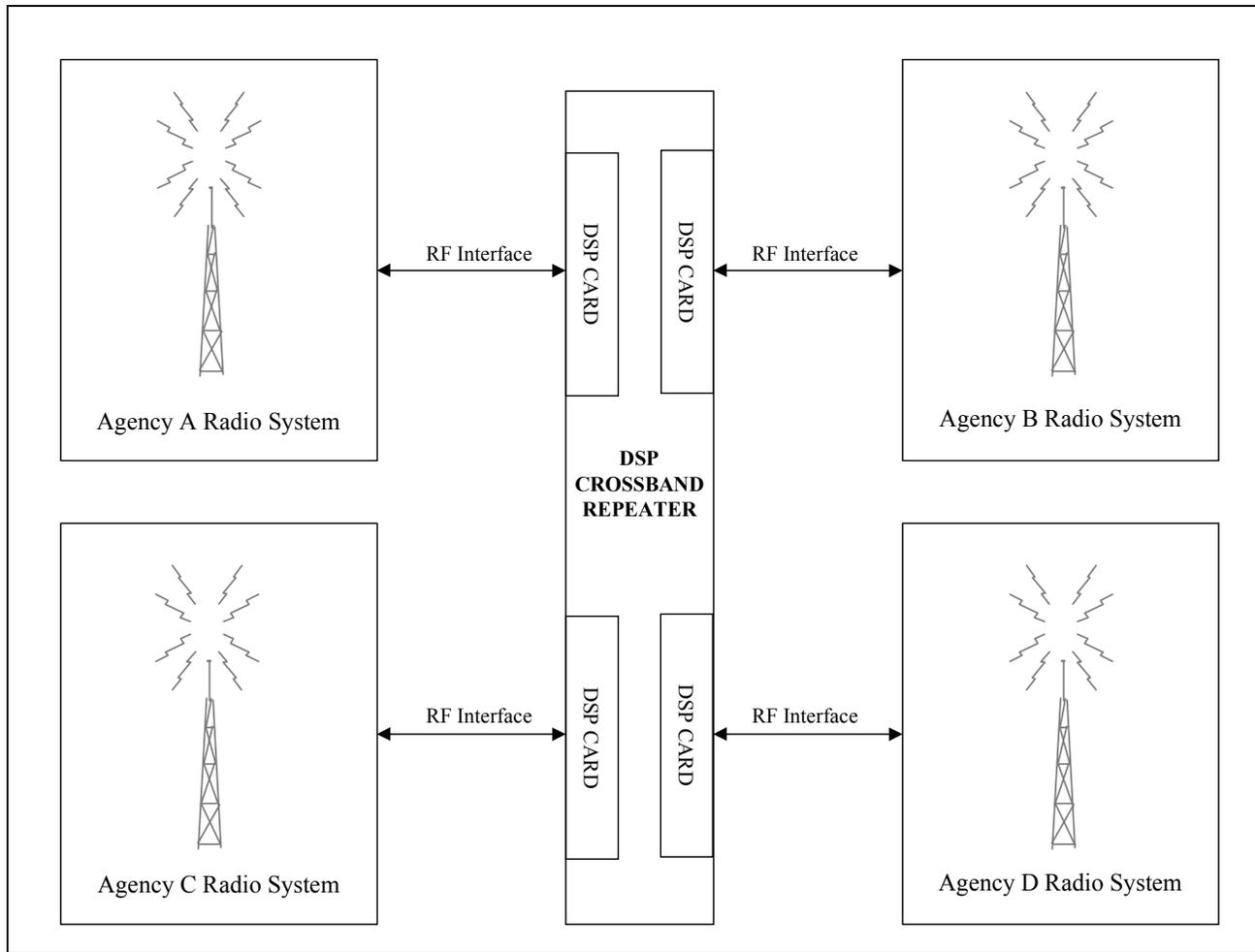
THE DRAWING BELOW ILLUSTRATES THE CONCEPT OF A MOBILE RADIO-MOBILE RADIO CROSSBAND REPEATER



THE DRAWING BELOW ILLUSTRATES THE CONCEPT OF AN AUDIO CROSS-CONNECT SWITCH REPEATER



THE DRAWING BELOW ILLUSTRATES THE CONCEPT OF A DSP CROSSBAND REPEATER



A CROSSBAND REPEATER IS A VIABLE SOLUTION WHEN—

- Agencies that need to interoperate use—
 - Different bands (for either conventional or trunked communications)
 - Incompatible trunked protocols
 - Otherwise incompatible systems, including—
 - Analog versus digital modulation
 - Wideband versus narrowband
 - Digital versus analog squelch codes
 - Incompatible digital modulation types and vocoders
- Several radio systems must participate in simultaneous call
- Subscriber units have room to add a common interoperability channel, and the infrastructure has the capacity to designate a channel for interoperability (sometimes, but not always)

EACH CROSSBAND REPEATER IMPLEMENTATION HAS ADVANTAGES

Advantage	Base Station	Mobile Radio	Audio Cross-Connect Switch	DSP
Is the ideal radio-radio interconnection because audio and PTT logic inputs and outputs are typically available; If VOX is unnecessary, this minimizes patch delay	✓		Nearly ideal ¹	✓
Requires little or no dispatcher involvement if a single interoperable channel is chosen because dispatch console intervention is unnecessary	✓	✓		✓ ²
Is typically automated; once activated, all broadcasts from one channel of one radio system are rebroadcast onto one channel of the second radio system (some delay possible)	✓	✓	✓	✓
Allows each agency involved to use its own subscriber equipment; no need to trade or buy radios that work on another system	✓	✓	✓	✓
Allows subscriber equipment to have only basic features; no need to switch between frequency bands or different modes of operation	✓	✓	✓	✓
Can accommodate several radio systems; several radio systems can participate in conference calls at once			✓	✓ ³
May be considered secure. Allows an effectively encrypted link via the internal interconnection; the transmit-and-receive audio does not travel outside unit				✓
Minimizes cost		✓		

¹Audio and squelch PTT logic inputs and outputs may be created if not already available. VOX may be necessary.

² Only one interoperability channel exists per DSP card.

³ Several radio systems can be accommodated provided few interoperable channels are necessary for each system.

Crossband Repeater Solution...Disadvantages...

EACH IMPLEMENTATION ALSO HAS DISADVANTAGES

Disadvantage	Base Station	Mobile Radio	Audio Cross-Connect Switch	DSP
Requires participants to decide which agency has primary control of interoperability equipment; agencies usually want to control their infrastructure completely	✓	✓	✓	✓
Requires training users to initiate a patch through the system and accommodate patch delays	✓	✓	✓	✓
May be necessary to use a dispatcher if each radio has several interoperable channels. Dispatcher must change channels centrally; remote channel changes are usually not possible. Dispatcher may also be required to activate/deactivate interoperable link	✓	✓	✓	
Requires pause for access to trunked systems; may increase need for user training and intersystem cooperation	✓	✓	✓	✓
May require reprogramming each subscriber unit involved to include interoperability channel. Potentially time consuming (depending on number of units) and costly (if reprogramming is performed by a vendor)	✓	✓	✓	✓

EACH IMPLEMENTATION ALSO HAS DISADVANTAGES (CONTINUED)

Disadvantage	Base Station	Mobile Radio	Audio Cross-Connect Switch	DSP
Requires sufficient fixed equipment infrastructure capacity to designate an interoperability channel. Although a channel can be added, doing so can be time consuming and expensive, both to coordinate and license the channel (especially in metropolitan areas) and to acquire and implement additional infrastructure	✓	✓	✓	✓
Necessitates an unencrypted link between radios, a security weakness	✓	✓	✓	✓
If audio and squelch logic unavailability will necessitate VOX, adding patch delay and complicating radio interconnection		✓		
Adds potential system to system oscillation problems when linking base station repeaters			✓	✓
Requires substantial or fairly significant investment	✓		✓	✓
Can be expensive if manufacturer modifies radios to provide COR or COS squelch logic output		✓	✓	✓

COSTS OF THE CROSSBAND REPEATER SOLUTION VARY DEPENDING ON THE IMPLEMENTATION SELECTED

- Base station implementation cost is significant because base station equipment costs are high and an extra base station could be required to interconnect with a repeater system
- Mobile radio implementation cost is minimal. An extra mobile radio is required to interconnect with a disparate radio system, but mobile radio equipment costs are relatively low
- Audio cross-connect switch implementation cost is reasonably significant because the technology is fairly new
- DSP implementation cost is significant because the technology is in its infancy

THE CROSSBAND REPEATER SOLUTION GENERALLY REQUIRES NO ADDITIONAL SPECTRUM

- This solution typically uses previously licensed spectrum resources, regardless of mode (conventional or trunked)
- If an additional channel is required, it may be time consuming and expensive to coordinate and license, especially in metropolitan areas

REPEATER SOLUTIONS REQUIRE SIGNIFICANT MANAGEMENT BY THE PUBLIC SAFETY AGENCIES INVOLVED

- Repeater solutions require training and possibly significant system development
 - Users must be trained
 - Dispatchers must also be trained if each radio has several interoperable channels
 - The pause for access to any trunked systems may increase the need for user training
 - Subscriber units may require reprogramming to include the interoperability channel, a potentially time-consuming and expensive process
 - If infrastructure capacity expansion is necessary, management is essential to control the time and costs required to license a new channel (especially in metropolitan areas) and to acquire and implement additional infrastructure
- Repeater solutions also require significant coordination
 - Participating agencies must decide which agency has primary control of interoperability radio equipment
 - Formal interoperability procedures should be developed to ensure that users follow established system procedures

MOST REPEATER SOLUTIONS DO NOT SECURE COMMUNICATIONS

- Participating agencies must accept another agency's having primary control of an infrastructure device in their communications system
- Implementations use an unencrypted link, such as the audio interconnection between radios, a security weakness
- Repeater solutions do not raise standards issues; their objective is to circumvent system incompatibility

CROSSBAND REPEATERS HAVE BEEN IMPLEMENTED IN LOCAL, STATE, AND FEDERAL PUBLIC SAFETY ENVIRONMENTS

The mobile radio implementation is used, especially in mobile command vehicles, by public safety agencies across the United States

- The PSWN Program has implemented this solution in the San Diego and Imperial Counties in southern California
- The PSWN Program is considering this solution in its Washington, DC pilot project