

ACU-M™ Improving In-Building Communications

Purpose

This application note will describe methods in which the Raytheon's ACU-M can be used to improve in-building communications.

The application note will discuss permanent and temporary methods at which different devices can help increase the ability to transmit or receive land mobile radio communications from within a building, below-grade, or behind obstructions.

Introduction

Land mobile radios, whether used in vehicles or as handheld portables, are an important tool used everyday by first responders to make their jobs safer and more efficient. In the most part, these radio systems function as designed, and serve the end-user with reliable communications. However, when the duties of a first responder require them to enter a building, or operate below-grade during emergencies, the ability of their radios to communicate to the base, incident command or dispatcher may become an issue.

One physical constraint of land mobile radio communications is its inability to transmit and receive radio waves through obstructions such as buildings or below-grade structures. The failure of a land mobile radio to transmit and receive communications from within a building or below-grade has cursed radio users since the beginning of land mobile radio communications (see Figure 1).

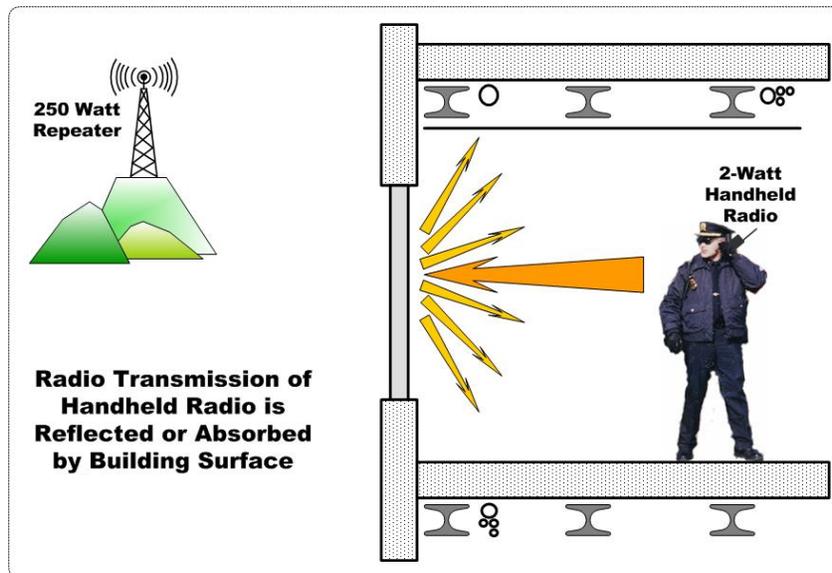


Figure 1: Blockage or Absorption of Low-Power Handheld Radio Transmission

Solutions

Land mobile radios were first introduced to public safety, in the late 20's, in the form of shortwave receivers mounted inside patrol vehicles. The earlier radio systems, used by the Detroit Police Department allowed only one-way transmissions from the headquarters to the patrol vehicle. It was never certain that the officer actually received the transmission. As technology progressed, communications allowed the officer to converse with the dispatcher in a two-way, half-duplex fashion. This occurred in the 30's with the Bayonne Police Department. Officers were now able to communicate to the dispatcher, headquarters and the other officers in the field.

The natural progression was to make the mobile radio, portable, hence the handie-talkie or handheld land mobile radio. Officers and firefighters were now able to leave their vehicles and communicate with their dispatchers, commanders and amongst themselves with small radios that they can carry on their belts.

One drawback of the handheld radio is its lack of transmit power (1 to 5 watts) to link to the main repeater of the radio system. Figure 2 shows that the mobile radio mounted inside a vehicle has a distinct advantage because it can usually transmit at much higher power levels (5 to 50 watts, or greater) than the portable radio, thus mobile mounted radios are more likely to link with the radio system's repeater, even through obstructions, such as the building, below.

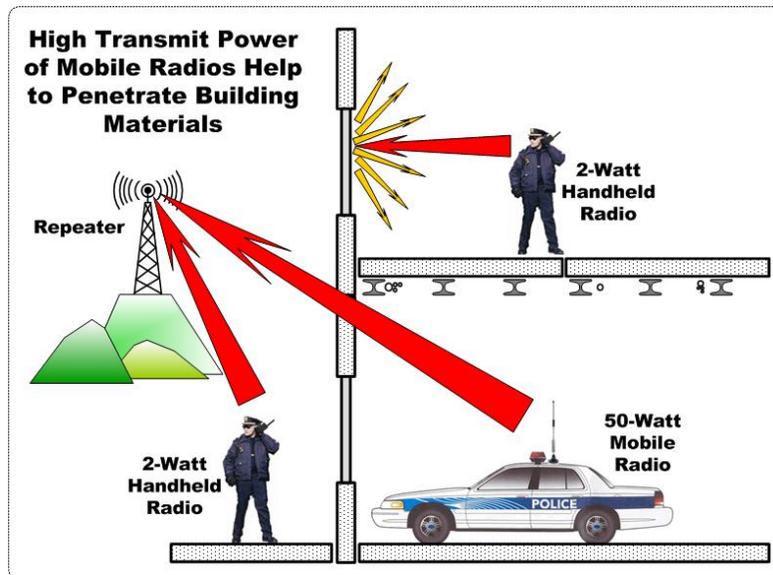


Figure 2: High-Power Mobile is able to Penetrate Building Material

Technologies such as receiver voters and comparators, multicast and simulcast are techniques used in today's modern radio systems that help compensate for the performance of the lower powered handheld radios. These techniques leveled the playing field, making handheld radios just as important to the first responder, as their mobile radios inside their patrol cars or apparatus.

However, when an officer or firefighter enters a structure he may be faced with the uncertainty that his handheld portable radio may not be able to reach the main repeater site or satellite receiver sites due to blockage as a result of the materials of the building surrounding him.

Some agencies have migrated from lower frequency radios (VHF) to higher frequency radios (UHF, 800 MHz) to take advantage of the improved “penetrating” properties of the shorter wavelengths, in attempts to counteract the signal-attenuating properties of the building’s surface (see Figure 3). Although VHF transmissions can travel around very large obstructions and travel many more miles than 800 MHz transmissions, VHF is no match for dense urban locations, where reflection and absorption of VHF signals is prevalent.

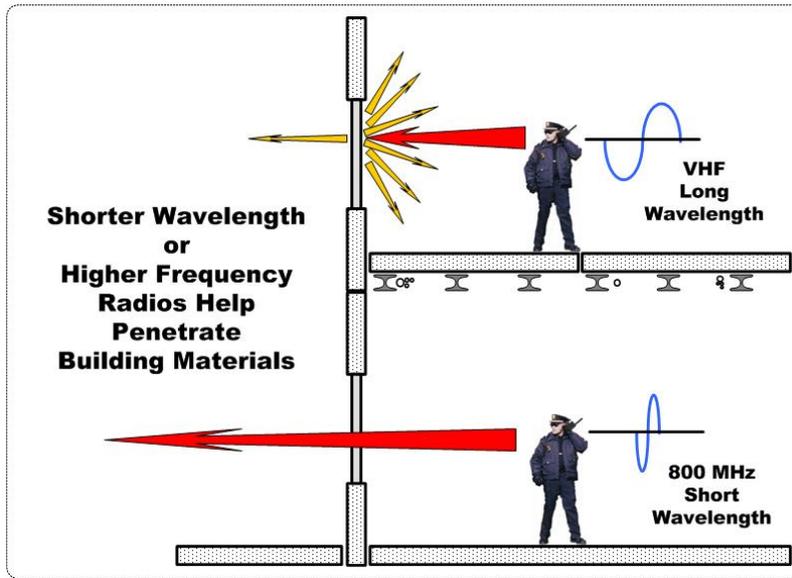


Figure 3: Improve Penetration, Shorter Wavelength is Better

In the dense metro environment, more and more obstructions are blocking the desired line-of-site (LOS) between the handheld radio and the repeater, and even higher frequency radio systems are not the answer. Additionally, building materials such as concrete, foil-insulation, steel and Low-E-Glass (low-emission glass), which has a microscopically-thin coating of light blocking metal oxide, can completely isolate the radio user within a building.

Permanent Solutions – Permanent in-building repeater systems can be used to create an electrical pathway that will allow transmissions to be routed from the inside of the building, to the outside of the building, through electronic means, and visa versa. One method is to place a receiver and donor antenna outside of the building to retransmit the low-power handheld radio transmissions that are picked up by distributed coverage antennas throughout the inside of the building.

Figure 4 illustrates transceivers, roof-top donor antenna, distributed interior coverage antennas and cables used in a permanent in-building repeater system. The low-power transmissions from the officer’s portable radio can circumvent the RF absorbing or RF blocking properties of the building material, and utilize an electrical pathway to the donor antenna on top of the building. Conversely, transmissions can be received by the donor antenna on the rooftop, amplified, and then routed to the numerous coverage antennas within the building, which then allows the portable radio inside the building to receive transmissions from outside. There exists similar in-building communication systems that distribute transmit and receive communications over fiber optic lines. In all cases, the transceivers used in these systems are called *Bi-Directional Amplifiers, BDA*.

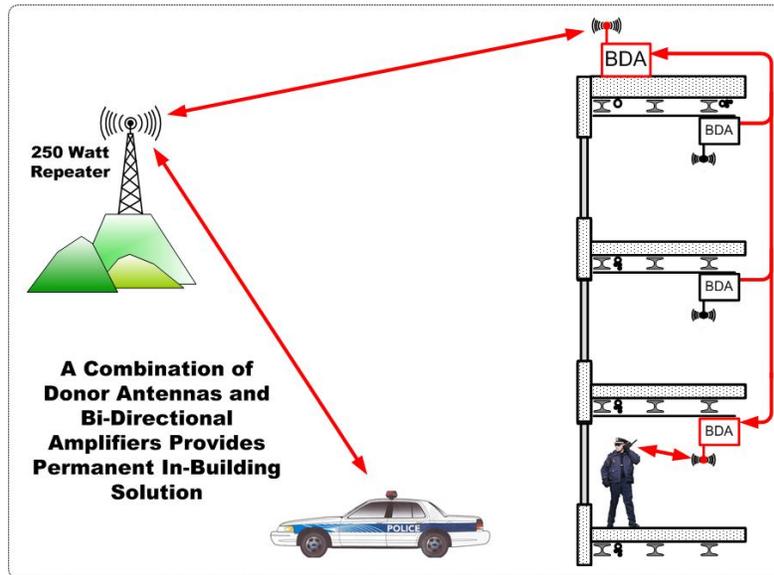


Figure 4: Bi-Directional Amplifiers, Permanent Solution

Instead of an array of transceivers, antennas and combiners, another method of signal distribution is to install a radiating cable or "leaky coax" along the vertical length of the building. The cable, with radiating slots along its length, would capture transmitted signals from the handhelds from within the building, and also leak transmitted signals receive from outside of the building, into the building from the donor receiver on the top of the building.

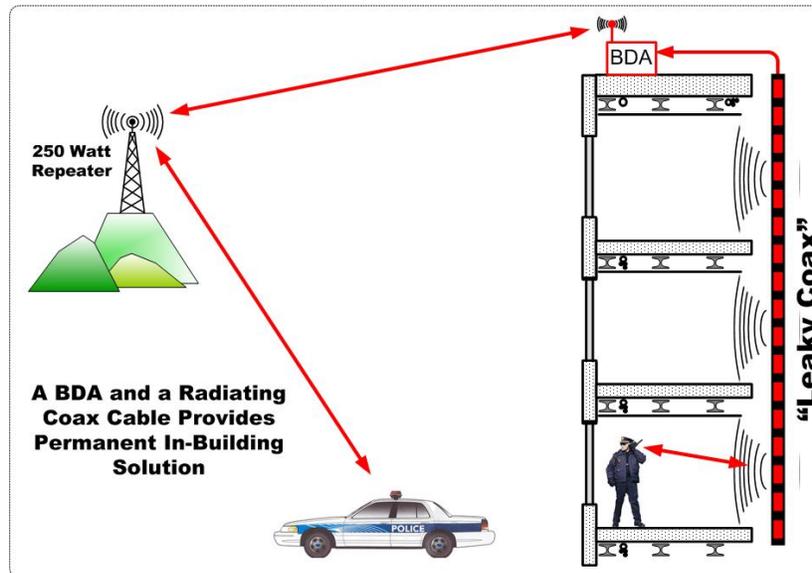


Figure 5: Radiating Cable, Permanent Solution

Figure 5 illustrates a permanent radiating cable solution that utilizes a BDA to facilitate the transceiver duties.

Although municipalities have started requiring new and existing commercial and government buildings of certain sizes and construction types to be equipped with permanent in-building repeater systems, there are many more municipalities unable to fund or put forth such directives to change their local building codes. These ill equipped buildings have become potential death traps to first responders and the occupants that they are sworn to protect.

Firegrounds Communications - Firefighters communicate using Hierarchical Communication system where the Incident Commander will communicate with several Team Leaders; and the Team Leader will communicate with the a 3 or 4 firefighter team inside the building. With this Social Communications Environment the Incident Commander will typically remain outside of the building relaying messages to the team leader inside of the building using land mobile radios. In some instances, the IC may enter the building using the floors below the incident as a command post. Whichever command structure is used at the firegrounds, this social method assures that no one person is responsible for too many tasks, the incident will remain modular, and since communications occurs in a hierarchal basis, this technique tends to reduce traffic and loading of the radio systems.

Communications techniques used by firefighters are varied. Some rely on repeated systems, and some on a dispatch environment, where the IC communicates with the dispatcher, and the IC relays messages to the team leaders at the firegrounds. But once the firefighter teams enter a building or underground structure, many fire service agencies may have no choice, but to practice the use of simplex or tactical communications.

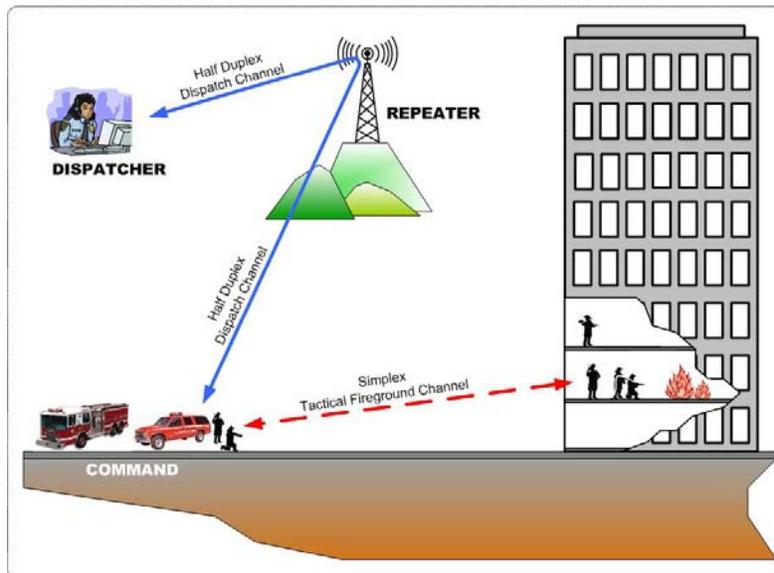


Figure 6: Firefighters Often Use a Dispatch Communications Hierarchy

In principle, simplex firegrounds communications is useful in an in-building incident because the radio communications using the main repeater between the incident commander, team leaders, and firefighters may not be possible due to the RF blocking properties of the building's surface. Figure 7 shows that the firefighters have switched their low-power handheld radios to a simplex firegrounds or tactical channel, and are now able to communicate in a localized fashion. The Incident Commander at the command post is also able to communicate with the personal inside

the building by utilizing a radio in a similar simplex tactical mode. These radios operating in simplex mode must all transmit and receive using the same frequency.

Additionally, the incident command usually has access to another radio that will allow him to communicate with the dispatch center using half-duplex methods (utilizing the system's repeater). This is important especially as the incident grows, the IC must be able to escalate the incident and request more companies or equipment at the firegrounds. It is not uncommon for the command post to have a number of radios performing different tasks.

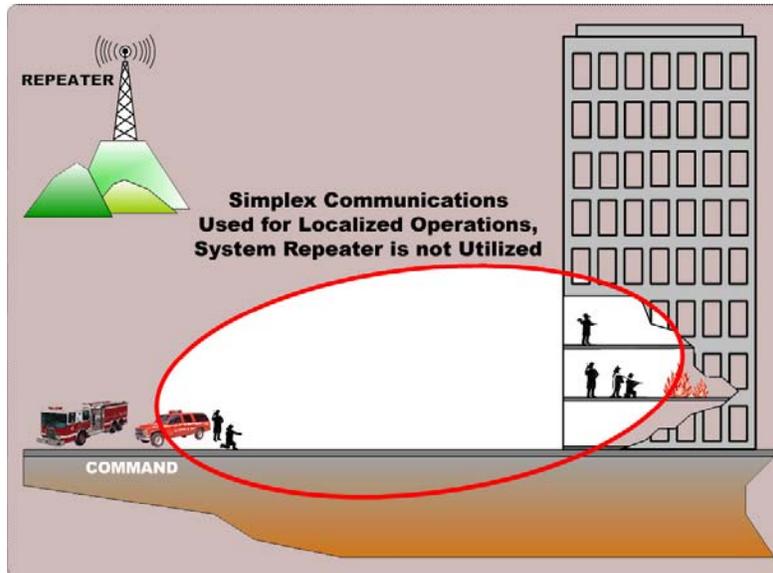


Figure 7: Simplex Firegrounds Communications Does Not Rely on Repeater

A residual benefit of simplex firegrounds communications is "Frequency Reuse". Since the radiating "footprint" of a low power handheld is rather small; the tactical channel can be "reused" at many spatially separated locations. Figure 8 illustrates frequency reuse of a tactical channel by three incidences that are not within the RF range of each other.

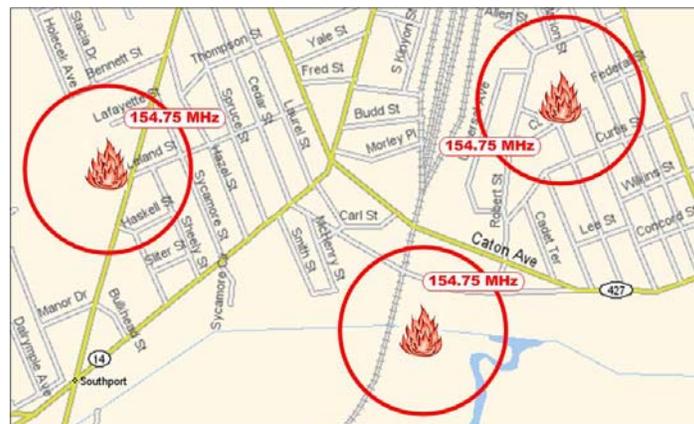


Figure 8: Several Simplex Firegrounds are Reusing the Same Frequency

Preferred by some fire agencies, utilizing the main repeater of the radios system allows the communications between the firefighters inside the building and the incident commander, as well, this arrangement allows the dispatcher to be in constant contact with all levels of command. If other buildings are involved in the vicinity, the other companies will be able to communicate in a collective fashion (see Figure 9).

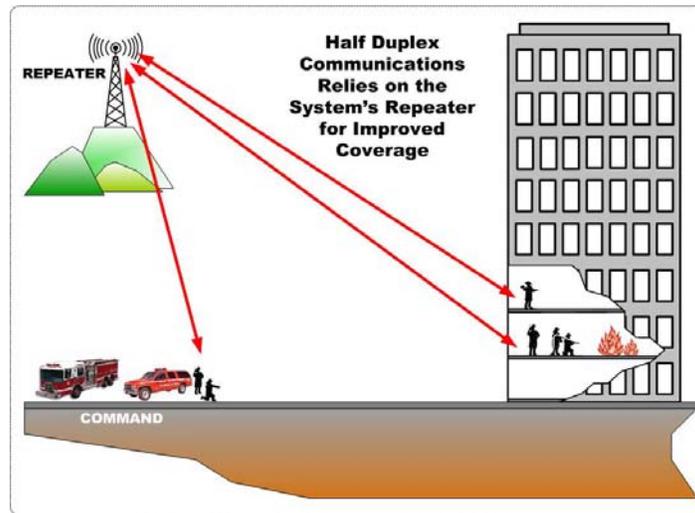


Figure 9: Firegrounds Communications Utilizing the System Repeater

Although simplex firegrounds communications has become a common practice with fire service agencies, public safety communications, ideally, relies on repeated communications. This assures that each police officer in the field has a communications link between the other officers in the field, as well as the dispatcher, just in case the officer needs to request emergency assistance.

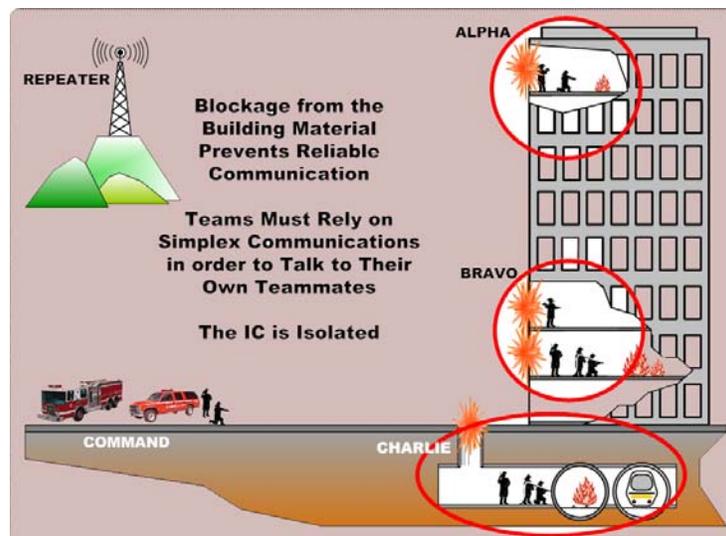


Figure 10: Building Material Blocks Communications Signals to the Outside

Portable Repeaters - Portable repeater receives weak simplex communication from inside the building, and then rebroadcast to the system's main repeater with a radio that can transmit through the building material with additional transmit power, or by utilizing a remote located antenna close to the outside of the building.

Figure 11 illustrates a basic portable repeater that contains one transceiver that interfaces with the system's main repeater, and another transceiver that interfaces with the in-building simplex communications. The repeater controller decides which transceiver rebroadcasts the communications at a given moment.

One of the advantages of a portable repeater is that it can be positioned directly within the building where the incident is taking place. The user can select the optimal position, which is a compromise between a good Line-of-Site (LOS) path to the radio system's repeater, and the low-power handheld radio users inside the building. When a portable repeater is placed inside a building, it needs to be positioned away from the core of the building, and preferably near the outer wall to afford a good link to the main system's repeater.

One disadvantage of the portable repeater is its weight can be rather heavy due to its integral battery. First responders will be burdened to carry another piece of heavy equipment into a building; along with the usual implements they carry to manage a fire. Portable repeaters also have an operating life cycle defined by the capacity of its battery.

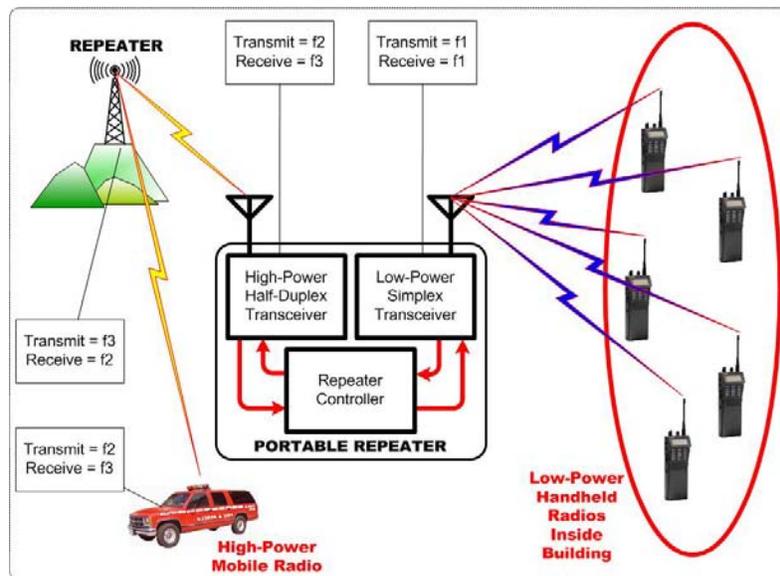


Figure 11: Portable Repeater Rebroadcast Simplex Communications

Using our previous building fire example, Figure 12 illustrates how one or more portable repeaters can be tactically located. Remember, the antenna must be positioned such that it can obtain a satisfactory link to the radio system's repeater. Note that the antenna of the portable repeater inside the subway tunnel has been extended above-ground. This is a necessity, but may be impractical due to the resistive loss of the additional length of the antenna cable. Excessively long antenna cables can reduce the transmit power and receive sensitivity of the portable repeater such that the repeater is no longer useful.

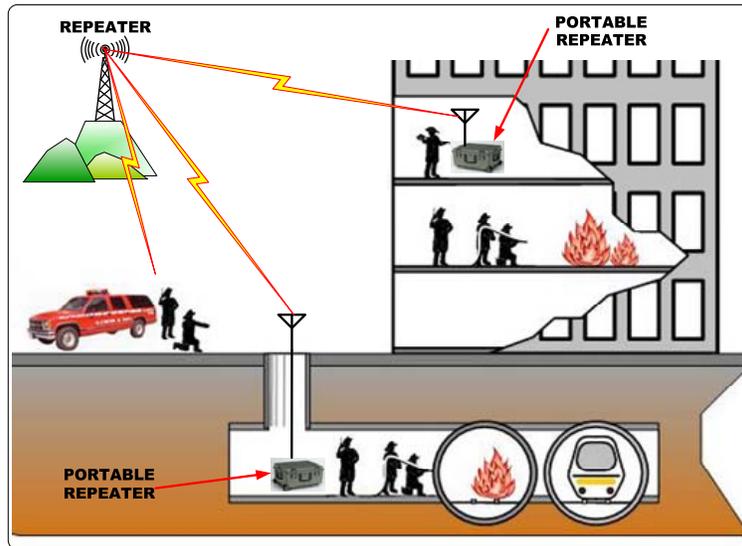


Figure 12: Portable Repeaters Located Inside Building, or Below-Grade

Vehicular Repeaters - Vehicular repeaters are an alternative to the portable repeaters. In essence, a vehicular repeater, which remains inside the vehicle, utilizes the more powerful transmitter of the mobile radio inside the vehicle, converting it into a secondary repeater. (see Figure 13). It is common practice to locate the vehicle close to the firegrounds or incident.

Example "A" illustrates how a low-power simplex firegrounds radio inside a building can communicate to the half-duplex system through the system's main repeater. This is a classic vehicle repeater application, also known as, *Range Extenders*.

Example "B" illustrates how the battalion chief uses his low power radio to send a high-power transmission to the simplex firegrounds radio users in a high-rise building. Example "B" is a common method of using a vehicular repeater at a firegrounds incident.

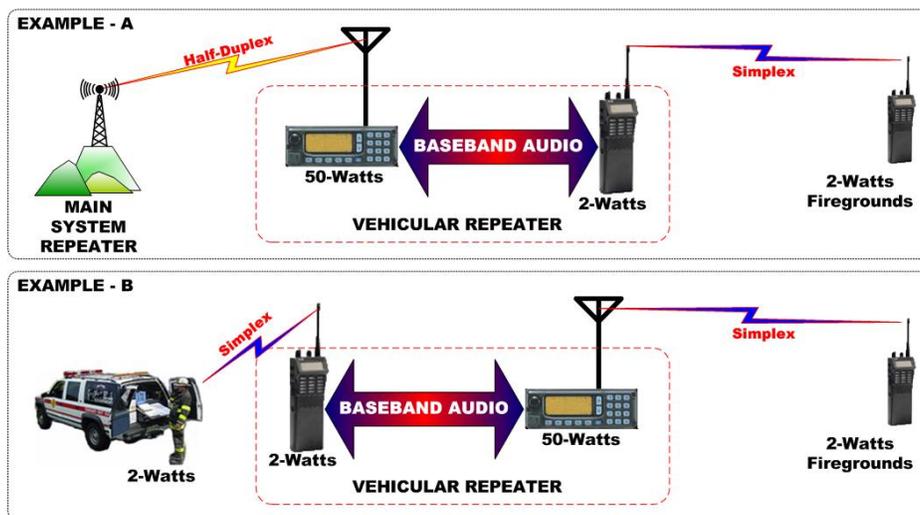


Figure 13: Simple Vehicular Repeater Utilizes Mobile Radio and Handheld Radio

The biggest advantage of a vehicular repeater is that it does not need to be carried into the building; it can remain on the apparatus where power is not an issue (see Figure 14).

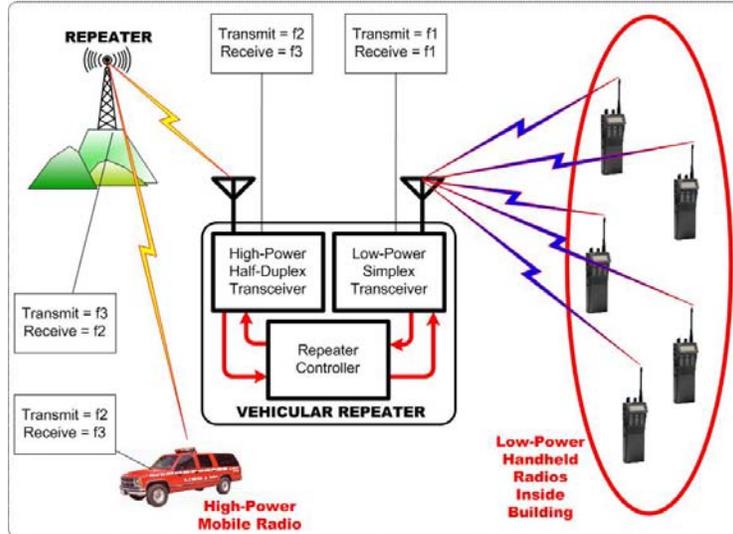


Figure 14: Vehicular Repeater Turns Radio inside of Battalion Chief Vehicle

Figure 15 illustrates how the battalion chief’s vehicle, which contains the vehicular repeater, is functioning as a secondary repeater site for the lower powered hand-held radios being used inside the building.

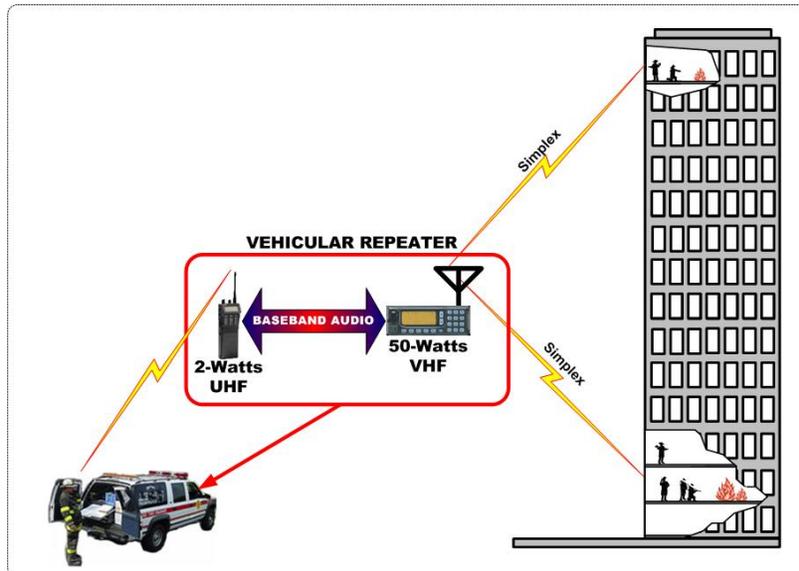


Figure 15: Vehicular Repeater inside Battalion Chief Vehicle Located Near Building

One important factor with regards to vehicular repeaters is that the vehicle supporting the repeater must be positioned in a tactical location that is relatively close to the building to assure a reasonable transmit and receive link to the low-power handheld radios within the building.

In Figure 15, the vehicular repeater contains a low-power UHF radio used to link the battalion chief to the repeater. The vehicular repeater also contains a high-power VHF radio that will link the firefighters using simplex communications back to the battalion chief. Physics tells us that the transmissions of the simplex users inside the building may not be able to communicate back to the battalion chief. But, the link will make certain that commands from the battalion chief will be heard by the firefighters.

Note that it would be imperative for the agency responsible for deploying temporary communication repeaters to perform periodic site surveys when dealing with in-building or below-grade communications, or other structures that could prove difficult to public safety communications when a real incident occurs.

Advantages and Disadvantages – Portable and vehicular repeaters, both, have advantages and disadvantages. Understanding how the temporary repeater will be deployed for each specific incident will help determine which method is more practical. The following tables list some of the common advantages and disadvantages of each temporary repeater type:

Vehicular Repeater	Advantage	Disadvantage
Power is less of an issued. Power derived from vehicle	✓	
No need to carry heavy case into building	✓	
Uses the radio already inside the vehicle	✓	
Less exposure to weather and elements	✓	
Able to support unorthodox repeater functions	✓	
Operator can remain in a safe location, inside vehicle	✓	
Difficult to misplace, attached to vehicle	✓	
Vehicle must be relatively close to building or structure		✓
Unable to easily support very tall buildings		✓

Portable Repeater	Advantage	Disadvantage
Power is self contained (battery), no power cords required	✓	
Can be positioned to optimize LOS	✓	
Able to serve a very tall building (multi positioned assets)	✓	
Configured in an adverse environment		✓
Can be misplaced		✓
Possible exposure to weather and elements		✓
Battery has a life cycle, discharge is an issue		✓
Must be carried into structure, heavy		✓
Must carry radios, antennas, cables, etc into structure		✓

Dealing with Interference – Portable and vehicular repeaters are unique, in that they, unlike permanent repeater solutions, can behave in unpredictable manner once deployed at the incident. Not only does the physical reaction to the surrounding materials (buildings, cars, terrain) determines the performance of the temporary repeater, but the radiating properties of the radio and transceivers used with the temporary repeater will play an important factor in the overall success of the repeater.

- Adjacent Channel Interference – One of the specifications that define a radio’s receiver is, *Adjacent Channel Isolation*. Adjacent channel isolation indicates how well a radio’s receiver rejects any extraneous signals that are just outside of the frequency or channel of interest. Naturally, we would only like to listen to a specific channel, and not hear conversations taking place on the adjacent channels. This is usually determined by the filtering used at the first mixer of the receiver. Figure 16 shows a properly designed radio receiver rejecting all adjacent transmitted frequencies.

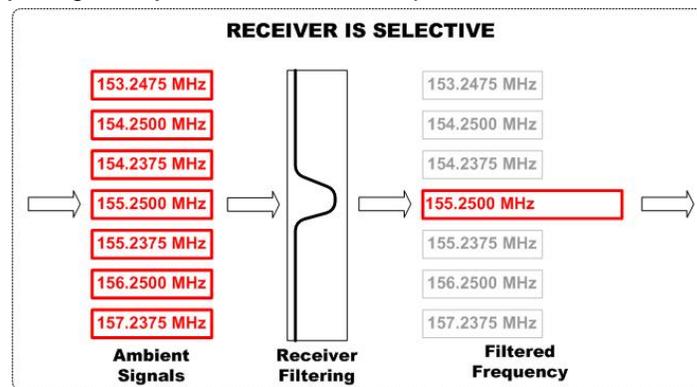


Figure 16: Properly Designed Receiver Filtering of Adjacent Channels

But, temporary repeaters discussed in this application note are inherently susceptible to adjacent channel interference, because they may contain high-power transceivers, and their antennas are in close proximity to one another. Figure 17 illustrates how the signal from a high-power radio can affect another radio’s receiver that is within close proximity. This is known as, *Receiver Desensitization* or *Desensing*.

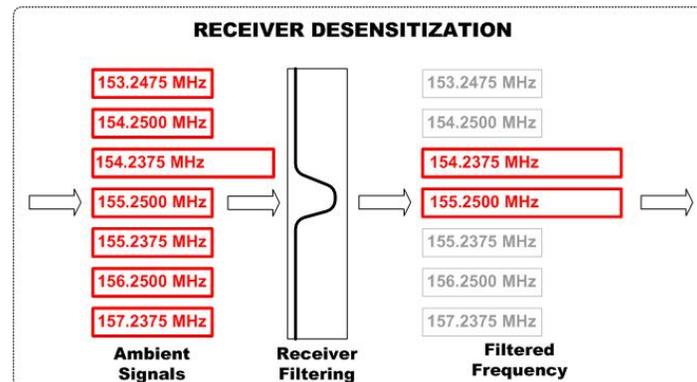


Figure 17: Receiver is “Desensed” From Adjacent High Power Transmitter

Even with properly designed receiver filters, the power emitted from high-power radios can be overwhelming.

- Solutions to Interference – There are several methods at which adjacent channel interference can be mitigated.
 - Cavity Filter - Cavity filters are commonly utilized to enhance the rejection of unwanted channels, but they can be large and difficult to tune during an incident. And if the channel is change at the radio, it will no longer be able to receive an adequate signal unless the cavity filter is also tuned to that channel.
 - Cross-Band Frequencies – By carefully selecting radios and transceivers that are not of the same frequency band, one can avoid interference, because the radios selected should have enough separation between useable frequencies (i.e. VHF/UHF, UHF/800). The disadvantage of cross-band repeaters is that the agency needs to possess the proper licensing for a radio frequency and radio equipment that they may not have.
 - Antenna Separation – Physically separating antennas vertically or horizontally will help prevent excessively powerful radios from desensitizing adjacent radios.
 - Directional Antennas – Paraboloids and Yagi antennas direct radio energy in specific directions, as opposed to omni-directional antennas, which radiate in a “donut” shaped pattern. Interference can be avoided by directing high-power transmissions away from the other receivers located at the temporary repeater.
 - Lower Transmit Power – Lowering the transmit power to get the task done, might not be the best alternative, especially for simplex communications. For instance, in Figure 15, the users on the upper floors of a high-rise building may not be able to receive the transmission from the temporary repeater if the transmitted power of the repeater was lowered. However, if the link is with the main system’s repeater, lowering the power to a level just enough to close the link should be sufficient to support communications. Too much power is simply not necessary.

Tests have shown that transceivers used with temporary repeaters can indeed operate within the same frequency bands (VHF/VHF, UHF/UHF, etc), if the transmit power and antenna placements are properly managed.

Gateway Devices as Repeaters – Interoperability gateway devices can improve in-building communications by providing a portable repeater functions, as well as providing communications interoperability as an aggregate function. The Raytheon ACU-1000™, ACU-T™ and ACU-M™ devices were designed to provide communication interoperability functions, and can inherently provide repeater type utilities.

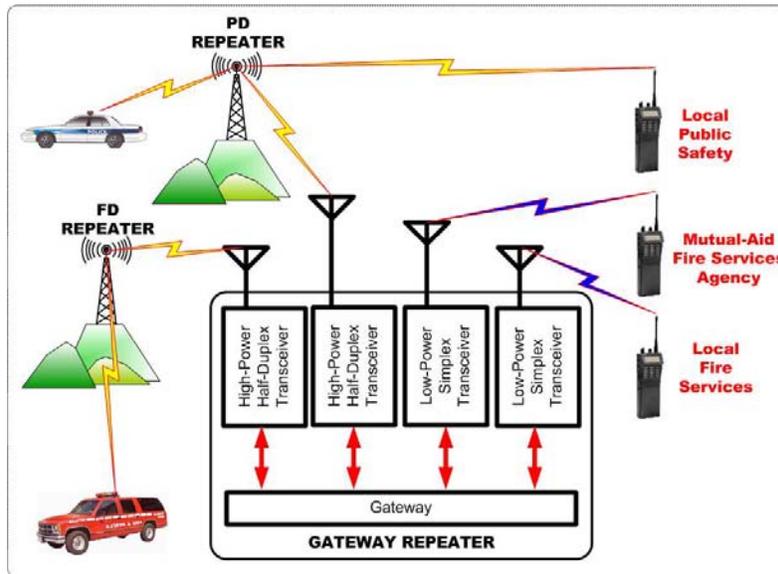


Figure 18: Gateway Repeater Provides Interoperability, Plus Portable Repeater Functions

Figure 18 is a block diagram that shows how the gateway can provide both, repeater and interoperability functions.

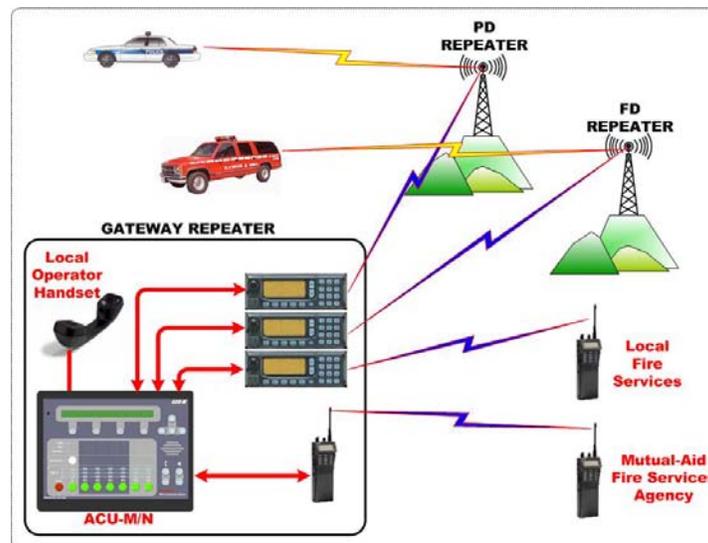


Figure 19: ACU-M as a Gateway Repeater

The ACU-M, ACU-1000 and ACU-T can be configured to function as portable repeaters or vehicular repeaters. However there are inherent advantages and disadvantages with each deployment which will be discussed further.

In Figure 19 the ACU-M is being used because of its size, and cost, however, the ACU-1000 and ACU-T both lend themselves well in these applications.

The ACU-M –

The ACU-M is feature-rich and can be networked and managed remotely. The ACU-M is an interconnecting device that will provide interoperability between 4 audio devices, plus 2 VoIP channels and a local operator (see 20).



Figure 20: ACU-M

The ACU-M incorporates the features of Raytheon's proven ACU technology into a smaller package ideal for mission critical deployment. With its comprehensive suite of DSP functions, the ACU-M offers high functionality at a price that fits any budget.

The ACU-M can be operated with a computer using the ACU Controller software graphical user interface, or the ACU-M can be operated completely autonomously, without a computer using its built-in onboard status and diagnostic LED's. The ACU-M also includes an internal pre-configured radio template library for all supported communications devices.

The ACU-M can also be purchased or electronically upgraded to provide network connectivity. Meaning the ACU-M will not only support tactical interoperability, but when electronically upgraded it can support RoIP communications and it can even be employed in Raytheon's Wide Area Interoperability System (WAIS™).

The ACU-M will support (4) land mobile radios, local operator's handset and (2) optional VoIP links.

ACU-M as Portable Gateway Repeater: The ACU-M was primarily designed to provide radio interoperability by allowing up to (4) land mobile radios to be linked together into up to (2) separate interoperable nets. In the previous block diagram, Figure 18 shows that one of the higher powered link radios is able to link to the main system's repeater, and that another link radio is able to link to the lower powered handheld radios that are within a building or below-grade. When these two radios are linked together by the ACU-M, communications between the different systems can take place (see Figure 21).

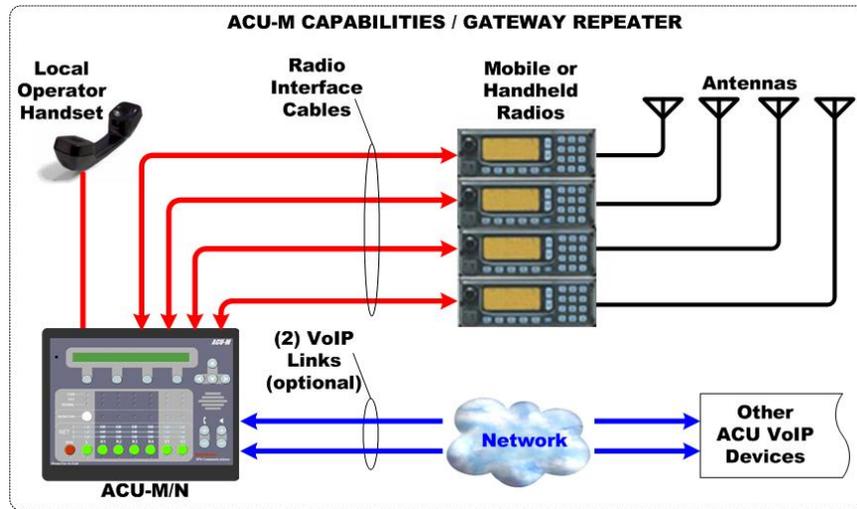


Figure 21: ACU-M Supporting (4) LMR's, (2) VoIP Links & (1) Operator's Handset

The same rules used by all portable repeaters hold true with the ACU-M as a portable repeater; transmit and receive frequencies of the half-duplex and simplex radios must operate at different frequencies, such that they will not interfere with each other. Although it would be ideal if the radios that the portable repeater were using were of different bands (i.e. UHF/VHF, VHF/800, 800/UHF, VHF/HF, etc), operating radios all within the same band are possible if the frequencies, transmit power and antenna positions are managed properly.

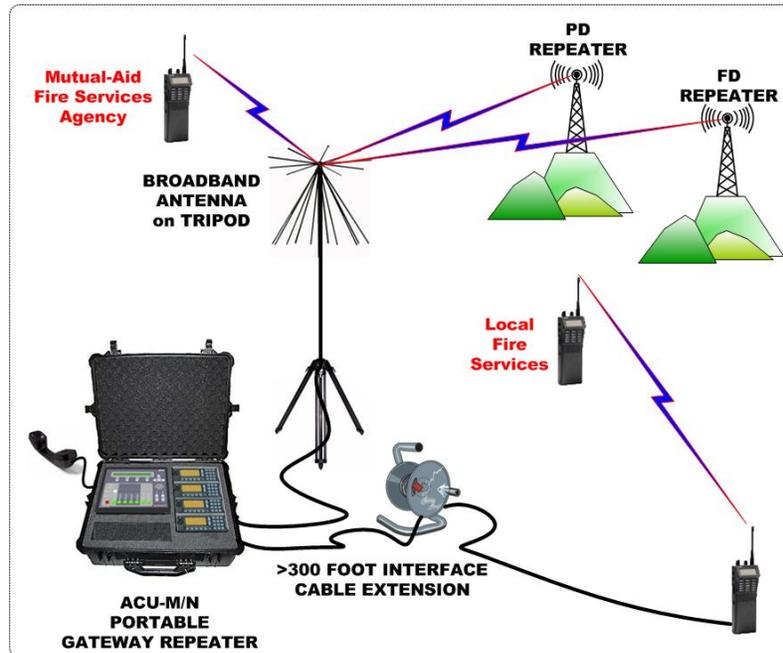


Figure 22: ACU-M Portable Gateway Repeater Mounted in Armored Case

Since the ACU-M portable gateway repeater will be deployed in environments where water and contamination will be present, it must be protected in a water resistant case and it must derive power from its own integral battery. The ACU-M is offered in a transportable case which address both power and containment requirements. The Illustration in Figure 22 shows an example of ACU-M and its link radios that are contained in an all weather case.

This example also illustrates the use of a broadband interoperability antenna mounted on a tripod. This unique antenna allows the user to connect more than one radio to a single antenna using a special coupler, reducing the amount of equipment to be carried into a confined space.

Additionally, a wire-reel containing several hundred feet of radio interface extension cable can be used to lower a simplex link radio into a tunnel, or extended a radio into areas of the building that are completely RF isolated (i.e. steel building). This arrangement is similar to a BDA system. Radio traffic is routed from a remote location using a cable, except, in this case the extension cable routes baseband audio, as opposed to the RF carrier of the radio. Baseband audio is less prone to line attenuation than the high frequencies of the RF carrier, which means several hundred feet of cable is easily managed by the ACU-M.

In this example the radio at the end of the radio interface cable extension is operating in simplex mode, and is allowing communications to the firegrounds personnel inside a RF isolated area of the building.

ACU-M as Vehicular Gateway Repeater: Since it is easy to see that the vehicular repeater is simply a derivation of the portable repeater, the description of the ACU-M used as a vehicular repeater is the same. Instead of using an armored carrying case, the ACU-M and link radios can be permanently mounted inside a vehicle.

The most ideal application of the ACU-M used as a vehicular gateway repeater is that it would be best served if it were install in the Battalion Chief's vehicle or in one of the "First-Arriving" apparatuses. Once on site, the high powered mobile radio inside the vehicle and the simplex link radio can be placed into an interoperability network, thus providing communications between the different classes of communications. When mutual aid begins to arrive from other agencies their radios can also be added to the net. Interoperability is one of the advantages of using a gateway as a repeater (see Figure 23).

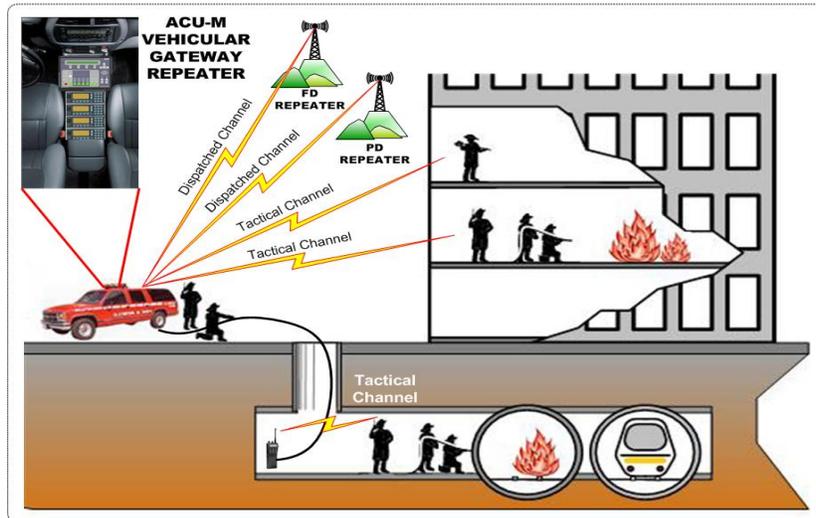


Figure 23: ACU-M Vehicular Gateway Repeater Mounted Battalion Chief's Vehicle

The installation of the ACU-M in a Battalion Chief's vehicle, whether that vehicle is a sedan, light utility truck, or SUV is easily installed on a light-weight mount on the dash or center console. The link radios can be installed in the trunk, or better yet in the center console, as illustrated in Figure 24. Mounting the equipment inside the cab of the vehicle facilitates easy channel and gateway/repeater management.



Figure 24: ACU-M and Radios mounted in Center Console of a Sedan, Light Truck, or SUV

Enhancing the ACU-M Gateway Repeater – The ACU-M used as a gateway repeater, whether in a portable or vehicular variety, has its advantages over typical portable and vehicular repeaters. The following illustrates several unique applications that can be used to enhance the ACU-M™ gateway repeater operations.

- Below Grade or RF Blocking Environments – When faced with operations within a below-grade structure, or when entering a building that will not allow RF transmissions to penetrate, long radio interface cables can be employed with the ACU-M gateway repeater. By attaching a portable radio to the end of a very long radio interface cable, the radio can be lowered into a tunnel or RF-blocked structure to provide a means of routing the signal in and out of the structure. This is made possible by the extensive audio dynamic range of the DSP (Digital Signal Processor) found in the ACU-M. It can compensate for the signal losses experienced when using extremely long radio interface cables.

The illustration in Figure 25 show a simplex firegrounds operation that is taking place in parts of the structure that are not conducive to radio transmissions. By strategically placing a link radio that are connected to the ACU-M via long interface cables around the building, simplex communication can take place. It is not uncommon to use 300-foot or longer radio interface cable extensions.

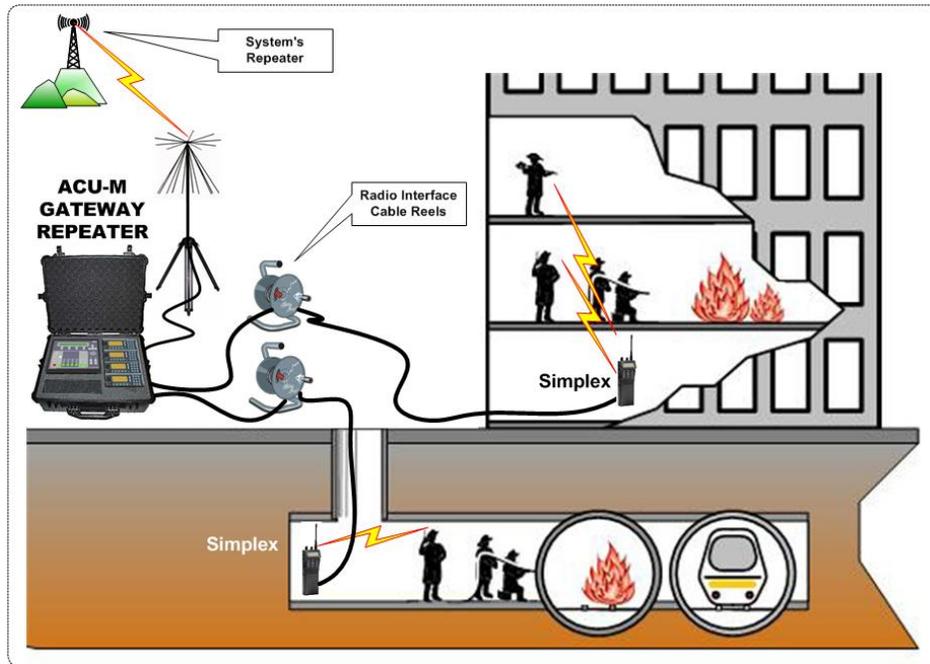


Figure 25: Use of Long Radio Interface Cables

- Extending a Link to Upper Floors using WiFi – Simplex communications in very tall buildings (+20 floors) can be all but impossible, due to signal blockage by the building itself, or by the use of low power simplex portable radios within. By utilizing wireless LOS methods (i.e. 802.x WiFi) a VoIP/RoIP link can be established between the ACU-M™ gateway repeater and a link radio on the upper floors of a building.

The ACU-M has (2) available VoIP/RoIP interfaces that are electronically activated options. Simply put, one of the ACU-M™ VoIP interfaces can be linked using LOS antennas, to an NXU-2™ located on the upper floors of the building. The NXU-2 or NXU-2A is a Raytheon device what converts VoIP/RoIP into baseband audio signals that are introduced to a connected radio. In this case, the NXU-2 would be connected to a simplex link radio which would allow first responders on the upper floors to be linked to the other simplex users operating closer to the bottom of the building.

The block diagram in Figure 26 illustrates the components required to create this extended link with the ACU-M. With the proper high-gain Yagi or parabolic antennas, WiFi access point, and network bridge, the radio user "A" (ground level) can communicate to radio user "B" (roof top) over an extended VoIP link.

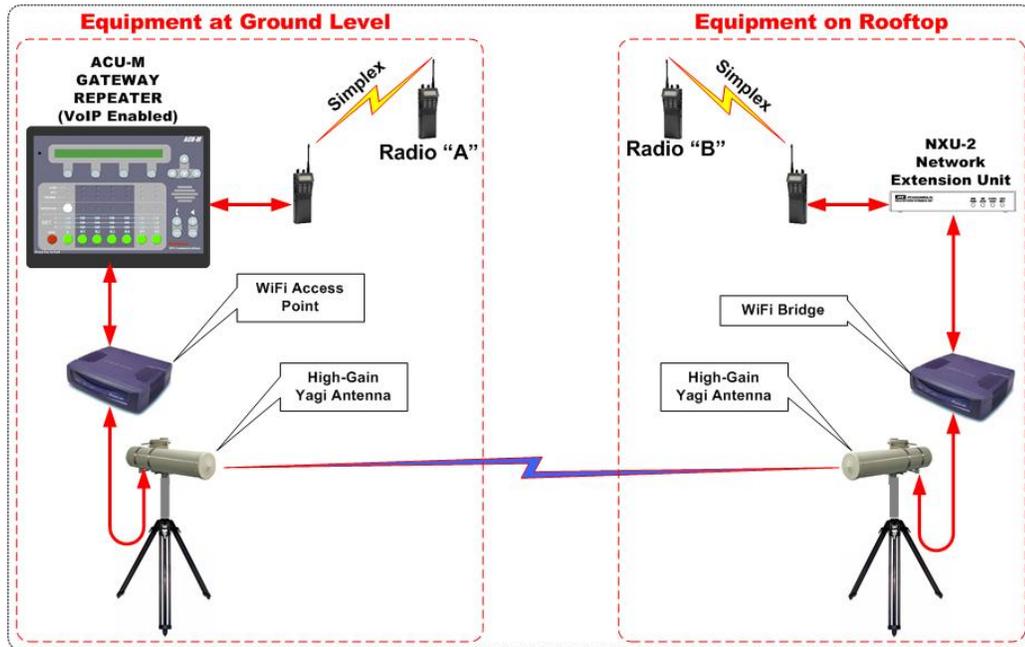


Figure 26: Block Diagram of Extended WiFi Link

Figure 27 illustrates how an ACU-M is utilizing its optional VoIP capabilities to create an extended link to a NXU-2 unit located on the upper floors of a high-rise building. As long as the WiFi antenna gain is sufficient, and that the Line-of-Sight is maintained, simplex users are able to communicate with other simplex users that are outside the radiating footprints of their radios (note: access point and bridge were omitted to simplify the diagram).

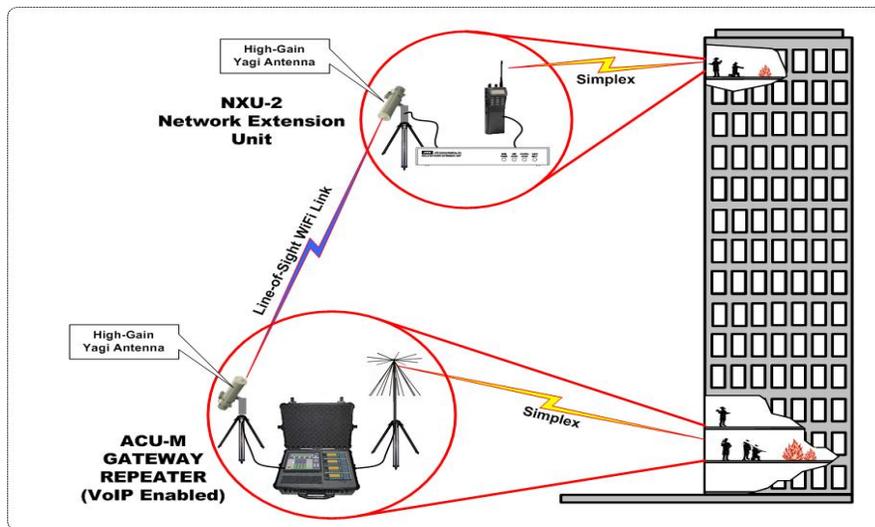


Figure 27: ACU-M Utilizing its Optional VoIP Feature with an Extended WiFi Link

- Multiple Distributed Portable Repeaters** – Several portable gateway repeaters can be distributed vertically to aid in the simplex communications that may take place on different floors inside a high-rise building.

Figure 28 illustrates an application where two or more portable gateway repeaters are strategically placed in a building directly across the street from an involved high-rise structure fire. Each of the portable gateway repeaters would contain simplex host radios of the local fire jurisdiction, as well as mutual aid agencies, which would link to the firefighters inside the involved structure. The portable gateway repeaters would also contain half-duplex high-power mobile radios that would then link to the main radio system's repeater.

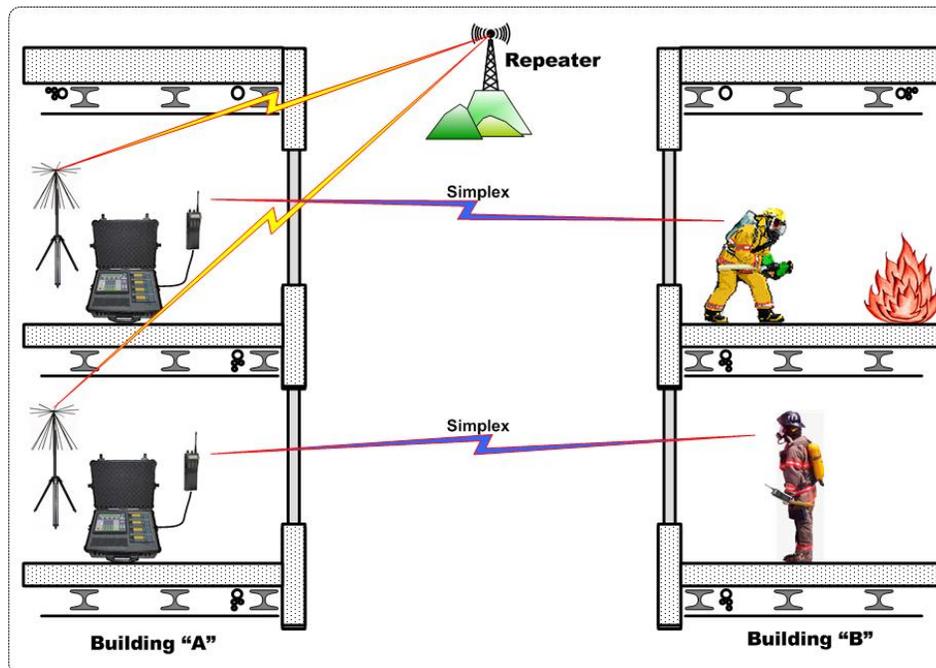


Figure 28: ACU-M Gateway Repeaters Positioned in Adjacent Building

Figure 29 shows several ACU-M portable gateway repeaters placed inside an adjacent building in a vertical arrangement. The simplex users in the involved structure will be able to communicate to the other simplex users in the building by linking their communications through the radio system's main repeater. A good rule of thumb would be to distribute a repeater every 10th-floor.

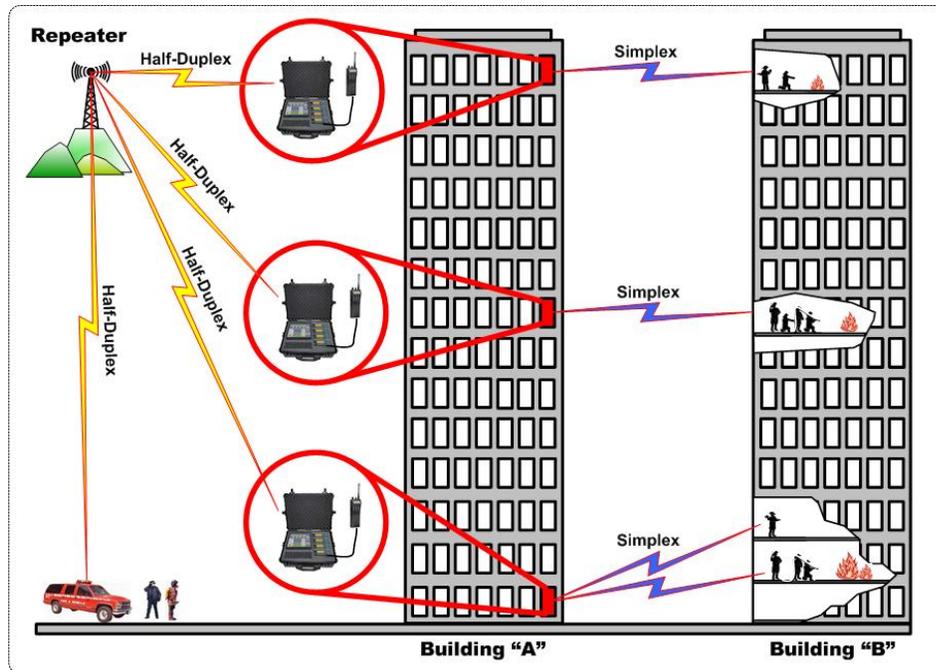


Figure 29: ACU-M Gateway Repeaters Links all Simplex Users through the Repeater

Advantages of Portable / Vehicular / ACU-M Gateway Repeaters – The following table lists the characteristics of the different types of temporary repeaters discussed in this application note:

Characteristic	Portable	Vehicular	Portable Gateway	Vehicular Gateway
Used where in-building communications is difficult	✓	✓	✓	✓
Can be positioned to optimize RF links	✓		✓	
Battery powered	✓		✓	
Can be multi-positioned to server high-rise buildings	✓		✓	
Uses mobile radio already mounted in vehicle		✓		✓
Power is not an issue (uses vehicle power)		✓		✓
Less exposure to weather and elements		✓		✓
Operator can remain in a safe location, inside vehicle		✓		✓
Difficult to misplace, attached to vehicle		✓		✓
Least amount of setup at incident		✓		✓
Can also provide communication interoperability			✓	✓
Can use extra long cable extension for below-grade operations			✓	✓
Can support extend RF WiFi links to the upper floor of a building			✓	✓
Support (4) land mobile radios			✓	✓
Support (1) Local Operator (Handset, standard)			✓	✓
Support (2) VoIP links (optional)			✓	✓
Patching can be controlled remotely (Ethernet)			✓	✓
Audio can be networked to other Gateway Repeaters (Ethernet)			✓	✓

Conclusions

The most ideal in-building and below-grade communications system is one that is already in place and does not require equipment setup by the first responders. Until our local and state managers and law makers set the directives that require reliable permanent in-building communications for our first responders, these permanent in-building and below-grade communication systems will remain few and far between.

And, as high-rise buildings and below-grade structures are slowly outfitted with BDA systems, temporary portable or vehicular repeaters will remain an important part of wireless communications for our first responders.

The ACU-M, with its (4) land mobile radio interfaces, and (2) optional VoIP interfaces is a natural fit as a portable or vehicular repeater, and at the same time, provide radio interoperability at the incident.

Acronyms

DSP: Digital Signal Processor.

LOS: Line-of-Sight describes a unobstructed free-space link from a source antenna, to a receiving antenna.

NXU: Network Extension Unit, is a device used to connect a DSP-1 module or a land mobile radio device over an IP-based network. The unit creates a network link that passes both voice and control signals in the form of RoIP.

RoIP: Radio over Internet Protocol, (compared to VoIP) not only converts voice to a digital format that can be sent over the Internet or other IP based network, but also convert PTT and COR control signals that are essential for seamless for radio interoperability. Also include are extra delay and jitter compensation.

VoIP: Voice over Internet Protocol, is a method of sending voice communications across a digital network.

WAIS: Wide Area Interoperability System is a Raytheon software application that can control many ACU's and NXU's over a TCP/IP network.

References

ACU-M Training and Resource CD, Raytheon

Richard Nowakowski, Raytheon

Wayne House, Emergency Services Sales and Grant Advisor, Raytheon