Vehicular Repeaters
In Fire/EMS Communications

By Bruce McPherson

1. Introduction

Today's public safety communications systems employ advanced technology to enhance the coverage, audio quality, and reliability required by modern emergency responders. The use of trunking technology, data communications, vehicle location, digital modulation, and computer-aided dispatch has made enormous strides in advancing the state of the art.

However impressive these technologies, the true test of an emergency communications system in today's environment lies in its ability to support handheld voice communications at the point of actual operations, in buildings with the fire attack or rescue team, or with the EMT at the side of the patient. The most advanced digital trunked radio system is of little use to the trapped firefighter who cannot get his MAYDAY distress call to the incident commander who can send in the Rapid Intervention Team to assist him.

Today's emergency operations rely on the use of handheld portable radios for in-building operations. However, many of the communications systems on which these radios operate, cannot penetrate the steel and concrete of modern construction, rendering the portable useless from within the building.

The Vehicular Repeater System (VRS) is an innovative and relatively inexpensive means of providing enhanced building penetration at the actual scene of an incident. When properly employed these devices will enhance the local Incident Command System. Although it does not provide all the features of full trunking system access, the VRS can provide an alternative to expensive upgrades or replacement of existing communications system infrastructure.

2. VRS Concept of Operation

The Vehicular Repeater System is fairly simple in concept and operation. It is based on the basic premise of "repeater" operations that have been around for many years. Unlike earlier single frequency simplex "talk/listen" radio systems, a repeater system employs two frequencies to support base radios that can simultaneously receive signals on one frequency and retransmit them on another. This is called half duplex operation. By placing these repeater stations in optimum locations, communications from low powered portable radios could be extended over a wide range to serve many users.

Today, all but the smallest public safety communications systems rely on the use of repeater technology. Even the advanced digital wide-area trunking systems employ repeaters as their basic radio technology.

As effective as fixed repeater technology is, its effectiveness in serving portable radios is largely dependent on the distance between an incident scene and the nearest repeater site. To insure full building penetration over an entire city or county might require so many repeater sites as to be prohibitively expensive.

In many of today's repeater based systems, including trunking systems, "talkaround" channels are employed. A talkaround channel consists of a single frequency simplex channel using the fixed repeater's output frequency. This allows direct local portable-to-portable operation without accessing the fixed repeater system. Disadvantages to talkaround operation include very limited range, the compound effects of building and body loss, as well as potential interference from the fixed repeater sites. In addition, talkaround mode does not support system level features such as PTT ID and emergency button signaling that are essential for firefighter safety in an emergency.

In recent years, technology has evolved to permit the use of repeaters in compact packages, allowing the repeater to be moved directly to the scene of an incident by the emergency responders themselves. In addition, mobile and portable radios have evolved to support a wide variety of frequencies and operating modes. Vehicular repeaters can now be used by the incident commander to support portable communications within the building or response area, and then be linked into the primary area communications system.

The basic structure of a vehicular repeater system consists of three principal parts. These are the mobile radio, the vehicular repeater, and the control head. Additional components include the antennas, duplexers, and notch filters.

The first part is the mobile radio. This is identical to the mobile radio unit that is normally used in any emergency response vehicle.

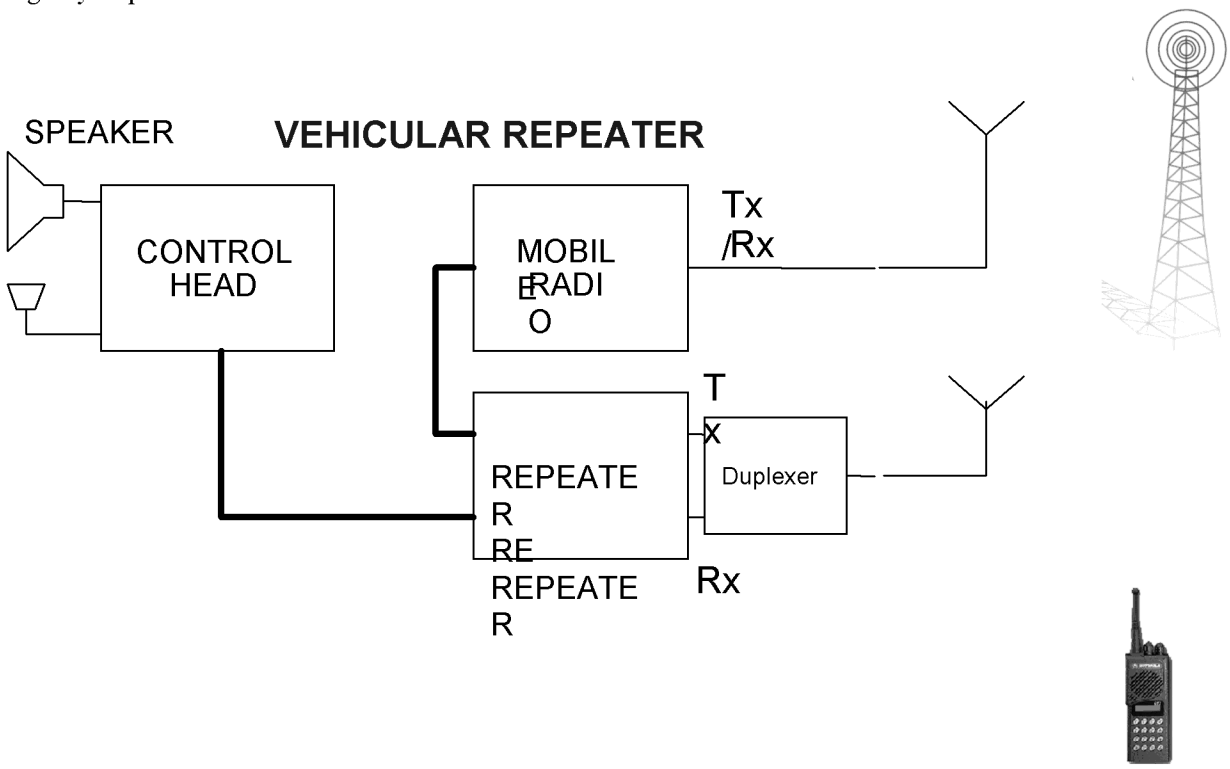

Figure 1. Vehicular Repeater

The second part is the vehicular repeater (VR) itself. This VR itself is a low power version of the fixed repeater stations that are typically used in the infrastructure. The VR will receive a signal from a nearby portable radio, and retransmit on a second frequency at power levels around 6-10 watts. This compares to the 3-6 watts typically used by the portable radios themselves. The increased power helps to overcome some of the losses from antennas mounted on speaker-mikes as well as the losses incurred in operating close to the floor of a building with heavy turnout gear. The VR is designed to run on 12 Volts DC, and connect to the mobile radio.

The final component is the control head, which is a modified version of the standard mobile radio control head. In addition to operating the mobile radio, the control head will also control the functions of the vehicular repeater, including displaying the ID of the portable radio.

A vehicular repeater system may provide up to three operating modes, as follows:

1. Mobile Mode
2. Local Mode
3. System Mode

Mobile Mode consists of the mobile radio operating alone, without the vehicular repeater turned on. This mode would be used during normal dispatch operations. The mobile radio is programmed to operate on the local public safety communications systems, whether trunked or conventional (non-trunked) in either analog or digital mode. The system may be low band, VHF, UHF, or 800 MHz, depending on the local system in use.

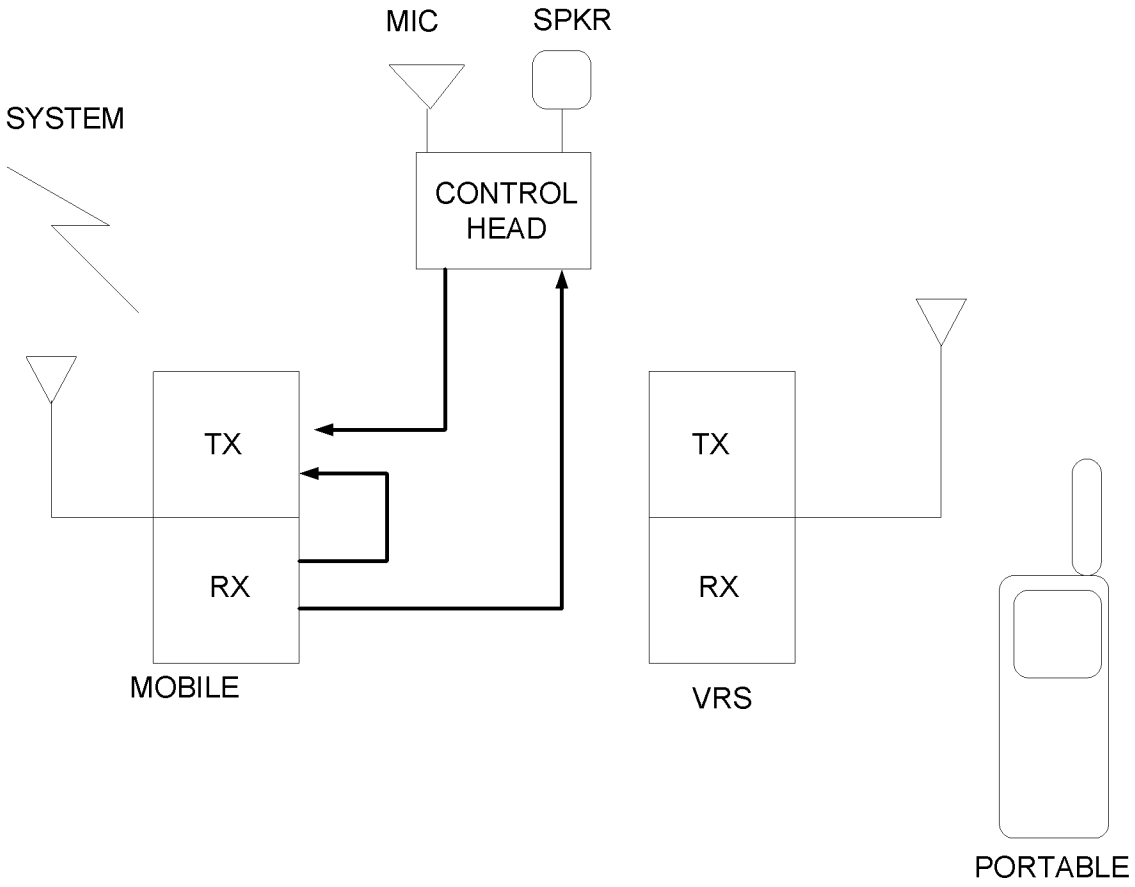

Figure 2. Mobile Mode

Local Mode employs the vehicular repeater on a separate frequency pair. On the scene of an incident, the vehicular repeater will retransmit signals from local portable radios that are on the right frequencies and have the right subaudible tone. The control head can be used to talk or listen on the local repeater

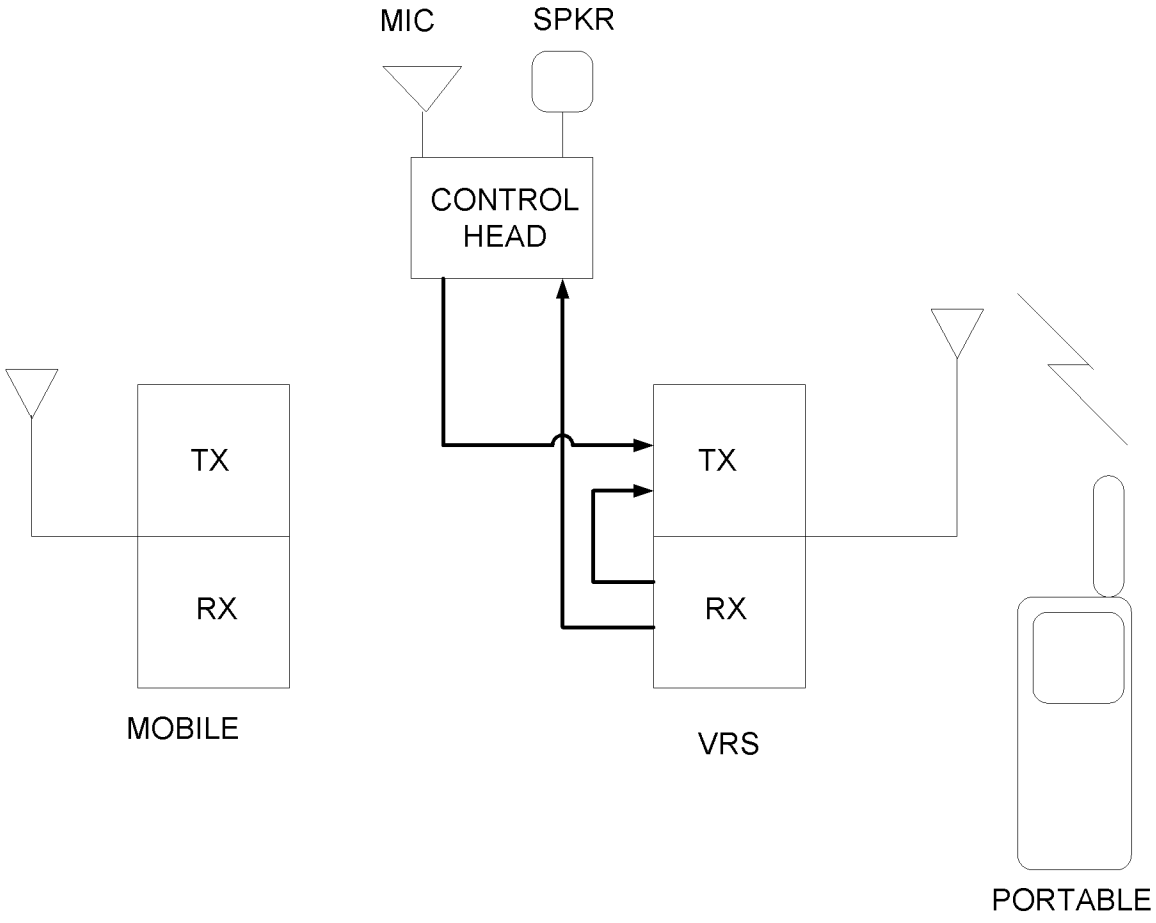

Figure 3 . Local Mode

System Mode allows the mobile mode and local mode to be interconnected, so that local repeater transmissions are retransmitted on the system frequencies, and vice versa. The control head may monitor from either side, and may transmit in either or both sides.

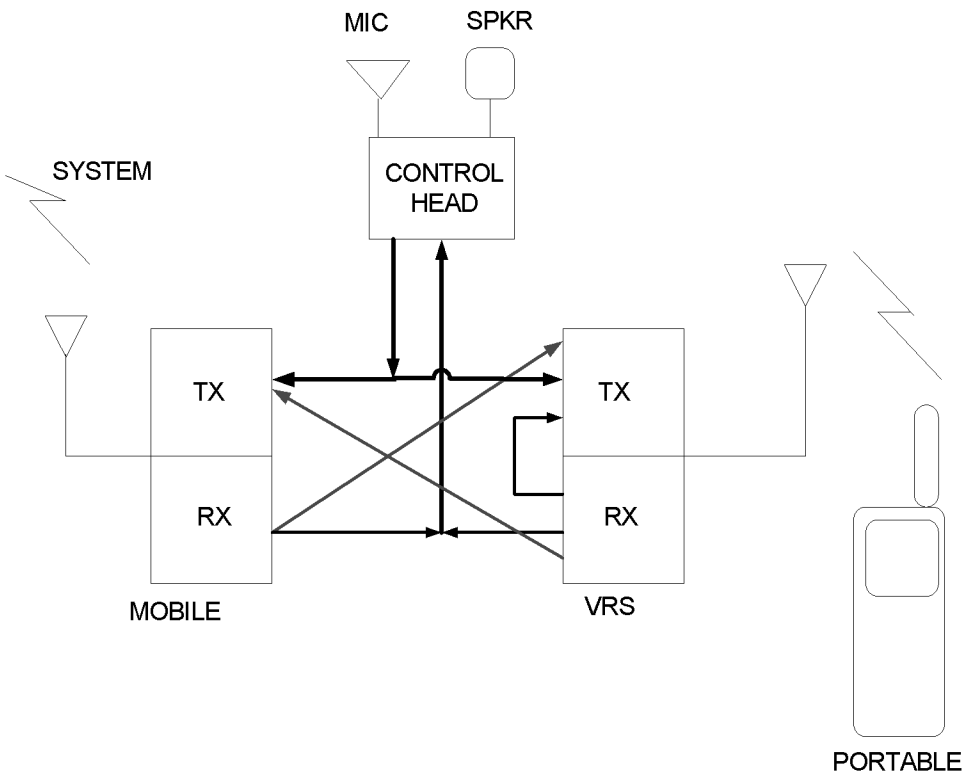

Figure 4. System Mode

Priority of transmission (portable, mobile, or system) may be programmed as desired.

The result is a highly flexible system that takes advantage of both the wide area capabilities of the primary communications system, as well as the superior in-building performance of a repeater system located right at the scene of operations.

4. VRS Advantages

Given all the expense of today's public safety communications systems, why would we incur the additional expense of a vehicular repeater system? The answer is that a well- designed vehicular repeater system greatly enhances the effectiveness of any public safety communications system at a fraction of the cost of additional infrastructure. Some of the advantages of VRS systems are listed below:

a. VRS systems use the same basic mobile radio units and control heads that would be required by the fixed radio system anyway, but only require the addition of a VRS unit and additional antenna. If at any time the VRS unit fails, it can be turned off, the

mobile radio will continue to function, and another VRS unit can be employed in its place.

b. VRS systems are not dependent on any particular fixed radio system. They can be used on low band, VHF, UHF, and 800 MHz systems, in trunked, conventional, analog, or digital systems. The portable radio operates in conventional analog mode, which is switch programmable on any modern system radio.

c. Either in-band or cross-band operation may be employed. Cross-band operation allows greater flexibility in acquiring usable frequencies for portable operation. In-band operation allows the same portable radio to be used for both VRS and system operation, by programming the appropriate channels in the portable.

d. Lower cost portable radios can be employed for building operation, since they will not need all the features required for system wide operation. Should they be lost or destroyed, replacement will not be as costly.

e. VRS systems may operate in local repeat mode in areas outside the normal coverage area of the fixed system, for example when operating in mutual aid in another community.

f. Specialized training is not required. The VRS employs the standard mobile control head with only a few additional switch functions.

g. VRS-equipped mobile radios need only be employed in selected command units, and not all mobile units. For example, VRS units could be placed in battalion chief vehicles, and used within the Incident Command System

h. Unit ID and emergency ID's can be displayed on the VRS control head, and can be re-transmitted on the fixed system.

i. Multiple portable link channels may be available on a single VRS unit, providing greater flexibility in employment.

j. The VRS brings more communications channels to bear for use on the fireground, without increasing the loading on the fixed radio system

k. Channels for the VRS device can usually be easily acquired and licensed due to their low power local operation

5. VRS Operation- Fire Service

The following describes how a VRS system might be employed in a typical building fire scenario. Although this scenario describes a particular type of application in a trunking system environment, this scenario could easily be employed in conventional systems in any frequency band.

1. 911 call is received at dispatch center. Appropriate units are dispatched according to local protocol on the trunked radio system dispatch talkgroup.
2. Engine companies, truck companies, and ambulances respond the call on the dispatch channel. In some trunking systems, a status button is depressed to indicate the responding status to the computer aided dispatch (CAD) system.
3. On arrival at the scene, incident command is assumed by first arriving unit, and subsequently by a battalion chief or other operations officer. The incident commander may operate on a designated command or field communications talkgroup that is used to communicate with the fire dispatcher.
4. If the incident commander decides that building coverage enhancement is needed in order to send entry teams into the building, he instructs them to set the selector switch on the portable radios to the tactical VR channel.
5. As the engine and truck crews operate within the building, they talk on the tactical VR channel. The other crews within the building use this channel, so that only incident related communications are heard on the channel.
6. If one of the crewmembers gets in trouble, he hits the emergency button on his radio to initiate a MAYDAY. This sends a signal to the control head of the incident commander with the ID of

the portable unit. Based on his accountability system, he will know the identity and approximate location of the unit, and can immediately get a LUNAR report or send in the rapid intervention team to respond. Depending on local protocol, other units not involved in the MAYDAY response may be steered to another tactical VR channel.

7. Depending on his control head settings, the emergency signal may be re-transmitted on the system channel with the mobile unit ID so that the field communications dispatcher can be alerted and he can focus his attention on the incident.
8. VRS systems can employ multiple portable link channels, with a bandpass duplexer in the VRS unit. This will allow multiple repeater channels to be used during a large-scale incident.

6. VRS Operation- EMS

Emergency Medical Service providers can also use the VRS system. The following scenario describes a typical VRS application during an EMS incident.

1. 911 call is dispatched. BLS and/or ALS units respond on the dispatch channel.
2. Upon arrival at the scene the paramedic or ambulance driver may set the mobile radio in the ambulance in the system mode on the assigned EMS operations channel if building coverage is insufficient.
3. The VRS channel allows the responder to communicate with other responders on scene, or to communicate with the EMS dispatcher. If necessary, medical consultation can be initiated by the EMS dispatcher while the patient is still in the building.
4. If the responder needs immediate assistance, he can depress the emergency button on his portable radio. The signal will be received by the VRS on the ambulance, displayed on the control head, and re-formatted over the system.

7. VRS Planning Considerations

While VRS systems provide many advantages, several factors must be considered when considering the employment of this equipment.

The VRS system employs a pair of frequencies for portable operation. These frequencies are outside the normal system channels, and must be acquired, licensed, and coordinated. While VRS systems have the flexibility to employ any common frequency band for the portable link, the use of a common frequency band for both the system and portable link will allow the use of a single portable radio for both system and local use.

In the 800 MHz band, specific channels have been set aside for low power local operation, making acquisition and licensing much easier.

VRS systems require sufficient isolation between the antennas used for the system link and the portable link. For example, at 800 MHz, a minimum of 5 MHz is required. In a typical 800 MHz application we may be able to use a trunking system in the 806 MHz sub-band along with a portable link in the 821 MHz sub-band. In in-band systems, antennas for the portable link channel should be physically separated from the portable link antenna as far as practical. If cross-band operation is used, the antennas need not be physically separated.

Since the VRS portable link operates on analog conventional channels, it will be necessary to either acquire low cost portables to operate on this link or to program existing portables with the additional frequencies and subaudible tones. In systems employing unit ID and emergency signaling, it will be necessary to program the required tones into the portable radios. Since these codes are not the same as the system ID codes, they can be programmed to display the actual fire company number and user number for rapid interpretation by the incident commander.

The possibility of multiple VRS units at an incident location must be considered. If two or more VRS units were operating on the same frequency pair in close proximity, interference could result. Advanced VRS units available today automatically disable all but one VRS units in range. Alternatively, multiple tactical VR frequencies could be used, or protocol could be developed that would authorize only the designated incident commander to enable his VRS at an incident.Because they represent an important new tool in the department's capabilities, the use of VRS systems should be incorporated into fireground and Incident Command protocols as well as EMS protocol. This tool will allow resources to be employed more effectively, with improved information capabilities and firefighter safety. This protocol should include the identification of best locations for VR units during pre-fire incident planning as well as handling of MAYDAY calls.

8. Summary

The Vehicular Repeater System is an important new addition to the communications resources available to the incident commander. They combine the range and flexibility of wide area communications systems with the ability to penetrate buildings through on-site repeaters. VRS systems enhance firefighter safety and provide improved capability and flexibility to the incident commander.

Biography

The author has over 20 years experience in public safety communications. He is presently a Senior Staff Systems Engineer with Motorola. He has been an engineer with Motorola over 10 years, and has also been a public safety communications consultant with RCC Consultants for over nine years. He has earned a Bachelor's of Science degree in Electrical Engineering form the University of Illinois and is presently working towards a Masters in System s Engineering at Johns Hopkins University. He holds both FCC commercial and amateur radio licenses. He is a certified engineer with the National Association of Radio & Telecommunications Engineers(NARTE). He is a member of the Association of Public Safety Communications Officials (APCO) and is a Lieutenant Colonel in the US Army Reserve (Signal Corps) H e has also been a volunteer Firefighter II & EMT at the Odenton Volunteer Fire Company in Anne Arundel County, Maryland for the last 11 years. He is presently a lead engineer in the digital upgrades of the Prince William County, Virginia and Anne Arundel County, Maryland trunked radio systems.