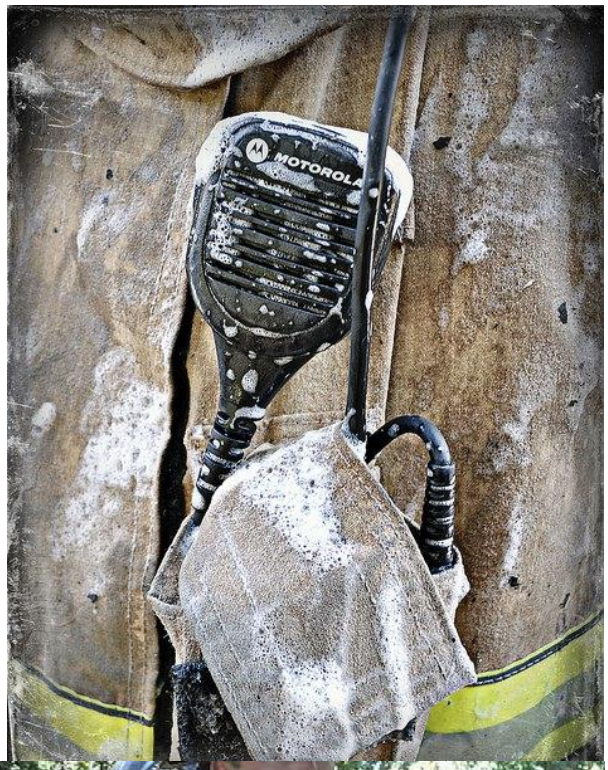
Portable Radio Placement in the IDLH

Fairfax County Fire & Rescue Department

Communications Section

1-2013



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EXECUTIVE SUMMARY

The issue regarding the placement of the portable radio while in IDLH firefighting operations has been long debated in the fire service. Most arguments center on the preference of the user or nebulous conjecture derived from documents or studies irrelevant to the placement of the portable radio in the IDLH. Some departments have gone so far as to develop policy dictating where firefighters will carry their radios when operating on the fire-ground. Fairfax County Fire & Rescue Department released a General Order in 2009 mandating the turnout coat radio pocket as the only way to carry the radio. Montgomery County (MD) Fire & Rescue have a similar policy.

The Fairfax County Fire & Rescue Department Communications Section set out to thoroughly research the issue and determine the safest location and best practice for carrying the portable radio during firefighting operations. Research started with contacting radio engineers to determine the signal loss issues. Additionally, there was significant review of numerous local and distant close-call and Line of Duty Death (LODD) reports, interviews and correspondence with firefighters and officers who encountered problems with their radios on incidents and training, review of relevant studies and reports, and examination of users wearing the portable radios in different manners.

Due to significant safety issues revealed during training and previous close calls, the radio pocket, as currently designed or modified, should not be used. The critical issues are numerous, but center around three fundamental problems when placed in the bunker coat radio pocket: Radio ejection from the pocket when subjected to a floor drop simulator or simply bending over to perform tasks relevant to firefighting, Exposure of the Remote Speaker Mic (RSM) to thermal insult that has on numerous occasions, melted the cord, exposed the wires, thus shorting the radio in an open transmit situation, and finally, radio signal loss associated with being in the pocket, which can be as much as 30dB; the highest degree of loss in comparable methods of wearing the radio.

Wearing the portable radio on a leather strap, under the coat, but with the radio extended below the bottom of the coat with the antenna canted away from the body protects the RSM from thermal insult and subsequent melting, eliminates 50% of radio signal loss over the radio pocket, and prevents the radio from ejecting of the person.

Three Critical Reasons why the Radio Pocket is *Unsafe*

1. Radio Signal Loss

- Validated data as a result of testing done with Motorola Radio Engineers concluded that of all the options available to firefighters, the radio pocket produced the most signal loss. Users should expect a 30dB signal loss while crawling, when stored in the pocket, which diminishes the power of a 3-watt radio to 0.01-watts. This is critical, not in the front yard, but when even in lightweight single family dwelling.

2. Portable Radio Ejection

- The Firefighter Survival Program conducted in 2010 revealed that the Radio Pocket has a *significant flaw* in its ability to retain the almost 2-pound radio during emergency procedures or even crawling during zero-visibility searches.
- In all four evolutions during the FSP, users experienced a 40% ejection rate. It was only through the validation of repeated Operations personnel going through the evolutions, were we able to *trend the significance of the problem*.
- Montgomery County FRS also trains department personnel in a Floor Drop evolution and noted a similar 40% radio loss rate when wearing the radio in the pocket.

3. Melting of the Remote Speaker Mic (RSM)

- Observed in several close call fires here and across the region, the RSM is the weakest or least protected part of the portable radio, also noted in the NIST report. Whether exposed when wearing it in the pocket or on a strap outside of the coat, when RSM melts, the braided wires often get exposed and short the radio in the open position. "This may result in a loss of functionality for the individual user, or, cause the RSM to short in such a way that the affected radio transmits continuously, creating an open mic situation, therefore jamming all communications on the fire-ground."
- This is a *Critical Safety issue*, as an open mic situation means that no one is able to transmit or receive during a MAYDAY event.
- **The RSM is best protected from Thermal Insult when worn under the coat.**

Concerns from those Opposed

1. Thermal Protection of the Radio

- Due to the NIST report, Testing of Portable Radio in the Fire Fighting Environment, there is concern that an un-protected portable will not function when exposed to heat; however, the experiment did not account for other factors experienced by firefighters operating at a real fire. Similarly, the sterile testing environment ***only*** tested an un-protected radio and a radio protected by a radio pocket. A leather case was not used, nor a leather case without exposed cut-outs for the screen and pads, as designed by the Communications Section.

2. Ability to Disconnect the RSM and use the PTT from the Portable

- Some argue that one would not be able to disconnect the RSM from the Radio Strap pouch in the case the RSM is melted and shorted out. Additionally, there is concern that if disconnected, the user would not be able to call for help if the radio is at the waist.
- The reality is that once the RSM is melted and shorted out, and the user realizes the radio will not work, it is not realistic to think that they will be able to troubleshoot and fix the issue with a gloved hand when experiencing a Thermal Emergency.
- In the event the user is unable to disconnect the RSM, one can successfully transmit using a portable, by bypassing the RSM, at the waist level; however, the recommendation is that users not use a retainer cord on the leather holster, so when the RSM is disconnected, the radio will come out of the holster to allow the user to bring the radio to head level.

3. Core Located Tools

- There has been some talk about the need to have critical items located at a Core Location such as the torso, based on *alleged* studies of firefighters in emergencies.
- ***No such validation has been produced.***
- The RSM is generally located at the same location, independent of where the portable is carried.
- The potential for the RSM to burn and short is dramatically reduced when under the coat, so the need to go to the portable to bypass a shorted out RSM is lessened.
- When a FFs hands are burning, the instinct is to protect the hands, either low or between the legs, but more importantly the instinct is to get out of the environment, not manipulate the connection to the RSM.
- When exposed to Rapid Fire Growth or Thermal Emergency, two things are lost:
    1. Ability to use fine motor skills
    2. Presence of mind

Comparison between Radio Strap and Radio Pocket		
	Radio Strap, Under the Coat, but Below the Coat line with an Exposed Antenna canted away from the Body.	**Radio Pocket**
Thermal protection of Remote Speaker Mic (RSM) Cord		
Prevention of unintended Portable Ejection		
Unobstructed Access to the Emergency Alert (EA) button		
Unobstructed Access to the Channel Selector		
Unobstructed Access to the Volume Knob		
Access to the PTT at Chest Level		
Access to the PTT at Waist Level		
Ability to Release or Disengage the RSM with one hand		
Ability for the antenna to remain vertical (by way of swivel) when crawling		
Height of radio knobs, relative to thermal ceiling on a 6-foot tall firefighter	**33-inches from Ground**	**56-inches from ground**
Amount of Signal "Loss" measured in decibels. **0 is Best.** While Crawling:	**15 dB**	**30 dB**
Amount of Signal "Loss" measured in decibels. **0 is Best**. While standing w/SCBA:	**7 dB**	**11 dB**
Ability to "Override" a stuck "Open Mic" due to melted RSM using the PTT on the Radio	Not possible on Single Transmit Mode	Not possible on Single Transmit Mode

Explanation of Comparison	
Thermal protection of Remote Speaker Mic (RSM) Cord	By placing the Portable in a Radio Strap (Under the coat, but below the coat line) the maximum level of protection is afforded (NIST, pg-5) to the most vulnerable component (NIST, pg-6) of the radio, the RSM. When placed in the pocket, the RSM Cord is exposed to thermal insult, resulting in a melted cord that will short the wires and potentially cause an open-mic scenario preventing anyone from transmitting.
Prevention of unintended Portable Ejection	By wearing the radio in a strap, under the coat, but below the coat line, the radio stays in place, by virtue of the waist strap on the SCBA. Momentum or velocity will not allow the radio to leave the pouch. In the report submitted by the Training Division, item-3 identifies a 40% radio loss/ejection rate in the floor collapse simulator. The Velcro closure has a manufacturer a limited number of open close actions before it no longer is reliable. Exposure to fires and the inability to secure the closure from snags or pulling the radio out in IDLH make it an unreliable method for carrying a 3-lbs radio. Ejection of the portable has also been reported numerous times to include the Primary Search School, roof top operations at a restaurant fire, and three other portions of the FF Survival Training, both in Fairfax County and Montgomery County MD.
Unobstructed Access to the Emergency Alert (EA) button	By wearing the radio in a strap, under the coat, but below the coat line, the user has an unobstructed, one hand access to the Emergency Alerting button. When worn in the pocket, the user must first pull the flap off, and often times pull the radio out to access and depress the EA.
Unobstructed Access to the Channel Selector	By wearing the radio in a strap, under the coat, but below the coat line, the user has an unobstructed, one hand access to the Channel Selector in event they must switch to Alpha, Oscar, or Papa to call for help. When worn in the pocket, the user must first pull the flap off, and change channels. This is a potential hazard if the firefighter is in the crawling position, as the radio may fall out in a zero-visibility environment.
Unobstructed Access to the Volume Knob	By wearing the radio in a strap, under the coat, but below the coat line, the user has an unobstructed, one hand access to the Volume Knob in event they are close to another firefighter or officer making a transmission. This may occur several times during a fire, because being in proximity to another radio with moderate to high volume will cause feedback in the other person's transmission. In-audible radio transmissions are often the source of communication problems in after actions. Having one-hand access to the volume allows easier access to prevent or reduce feedback as a result of nearby radios. It is also a documented best practice. When worn in the pocket, the user must first pull the flap off, and adjust the volume. This is a potential hazard if the firefighter is in the crawling position, as the radio may fall out in a zero-visibility environment.
Access to the PTT at Chest Level	By wearing the radio in a strap, under the coat, but below the coat line, the user has access to the PTT at chest or neck level. This could be important if a firefighter is trapped or pinned due to a collapse. Wearing the radio in pocket also affords this ability.
Access to the PTT at Waist Level	By wearing the radio in a strap, under the coat, but below the coat line, the user has access to the PTT also at the waist level. Based on the way the firefighter is pinned, either hands up by the head or hands by the waist in a normal position, the user has access to the PTT button(s) in event they need to call a MAYDAY. Wearing the radio in the pocket *limits* access to the PTT to the chest area ONLY.

Ability to Release or Disengage the RSM with one hand	By wearing the radio in a strap, under the coat, but below the coat line, the user has one hand access to the connection point to the RSM, thus allowing the user to disengage the RSM if their cord is melted and shorted out. In either case, it is not an easy feat with fire gloves in a super-heated thermal emergency, from a practical perspective. In order to disengage the RSM connection when wearing the radio in the pocket, the user must pull the flap; keep the flap in one hand while pulling the radio out with the other hand. Then he or she must disengage the RSM connection while holding the radio.
Ability for the antenna to remain vertical (by way of swivel) when crawling	By wearing the radio in a strap, under the coat, but below the coat line, the radio is in a swivel position, when coupled with an engaged SCBA waist belt. When the user is standing the antenna remains vertical. When the firefighter is crawling, the antenna is virtually vertical. It was noted in the PWDFR Radio Test Final Report (Pages F-4&5)," *The portables obtain the best signal strength when operated with the antenna in a vertical position."* When the firefighter wears the radio in the pocket and is crawling, their signal strength is reduced to .01 Watts with 30dB Loss of an available 3-Watts in a radio (City of Fairfax Radio Signal Strength Study Page-3).
Height of radio knobs, relative to thermal ceiling on a 6-foot tall firefighter	By wearing the radio in a strap, under the coat, but below the coat line, the radio is positioned lower towards the floor by almost 2-feet. 2-feet is significant, as it relates to thermal temperatures both in long-term heat exposure (the duration of time leading up to an extreme spike in temperature) and rapid fire growth emergencies. Examples of thermal damage and charring can be found in the Southern Motel Fire Close Call Report 2006-003, pages 20-27. The difference in the thermal damage at the pocket level, as opposed to the pant pocket level, where the pouch resides, is significant.
Amount of Signal "Loss" measured in decibels. 0 is Best. While Crawling:	During the City of Fairfax Fire Department Radio Signal Strength Study, radio "positioning" was tested in numerous potential positions. Comparing the "strap under the coat with antenna exposed" versus the "radio pocket" was conclusive. The radio pocket generated 30 dB loss while crawling, which tranlates to making a 3-watt radio a 0.01-watt radio. In marginal signal areas or in earth covered basement, or highrises, this level of loss means that the firefighter will not only be unable to call for help, but also hear potential critical radio traffic. To put into perspective how important loss is, PWDFR opted to not activate the VHF portion of their new APX portables, because doing so generated an additional -2dB of loss. -2dB was too much of a risk to their firefighters to flash the already installed VHF feature in their new radios.
Amount of Signal "Loss" measured in decibels. 0 is Best. While standing w/SCBA:	See above.
Ability to "Override" a stuck "Open Mic" due to melted RSM using the PTT on the Radio	The notion that simply depressing the main PTT on the body of the portable (through the radio pocket material) to override a stuck or open mic (as a result of melted RSM cable) is not possible, since our system is in single transmit mode. Only one user can have access (PTT) to the talkgroup at any one time. If the RSM mic portion is simply not working, then depressing the PTT will work, but it will also work at the waist level by tiliting the portable up and talking down.

Photos of the Radio Pocket in Use

Figure 1 – Typical application of the flap.

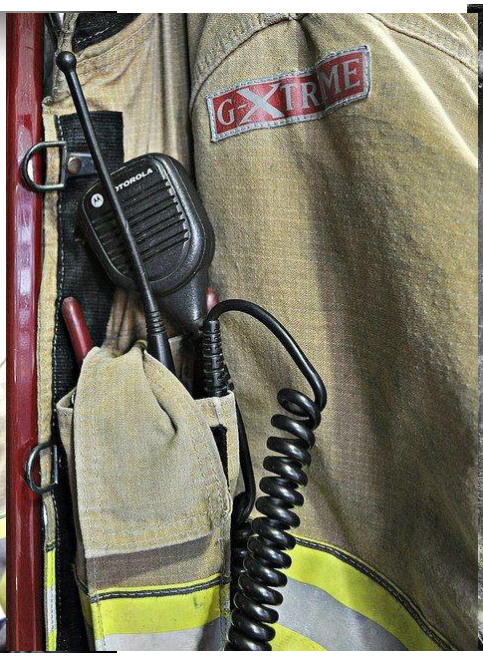


Figure 2 – Properly applied flap.

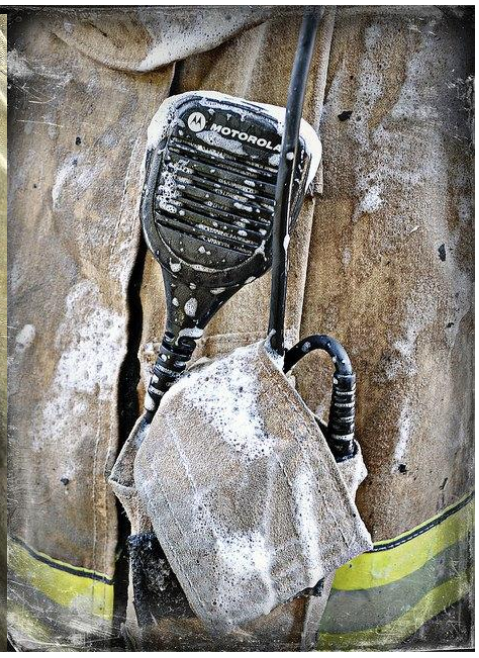


Figure 3 – Typical application of the flap.

Figure 4 – Portable radio is close to falling out, as this firefighter is operating over a ventilation hole on a roof.

Photos of the Radio Pocket in Use

Figure 5 – Typical post fire application of the radio pocket flap. Notice exposure of the RSM and the Thermal imager and high pressure SCBA hose; which often interfere with the radio pocket closure.

Photos of the Radio Strap in Use

Figure 6 – Notice the angle of the antenna (away from the body) when worn under the coat, as shown on the left. The strap – worn outside of coat – as shown on the right is NOT Recommended due to exposure of the RSM to thermal insult.

Figure 7 – Worn under the coat with the antenna naturally canted away from the body.

Figure 8 – Strap worn under the coat and protruding out of the natural gap between the buckle flap and collar flap. The majority of the RSM cord is protected.

Figure 9 – Another example of the antenna canted away from the body naturally, eliminating up to 15-decibel loss over wearing it in the pocket.

Photos of the Radio Strap in Use

Figure 10 - Another example of the antenna canted away from the body naturally, eliminating up to 15-decibel loss over wearing it in the pocket.

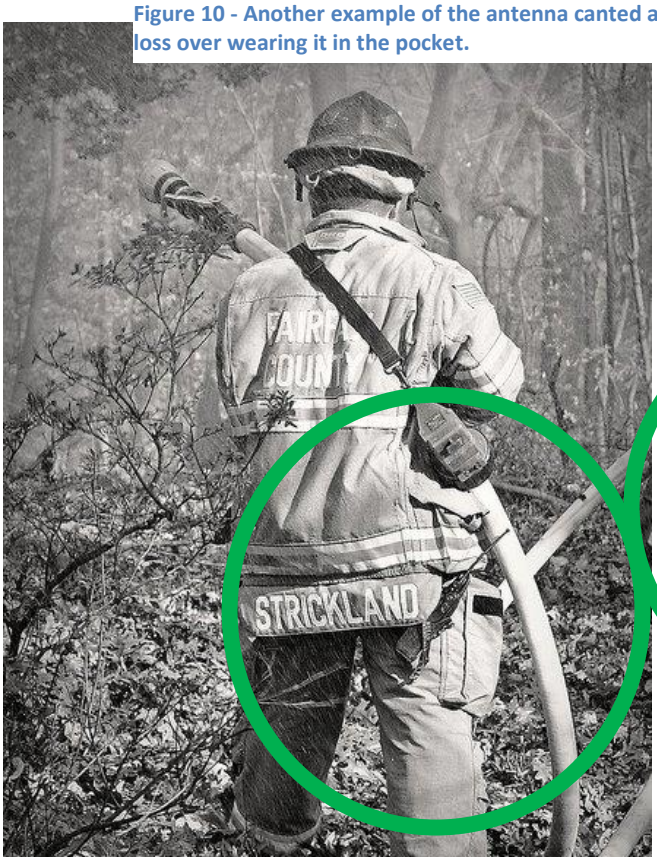


Figure 11 - Another example of the antenna canted away from the body naturally, eliminating up to 15-decibel loss over wearing it in the pocket.

Figure 12 - Another example of the antenna canted away from the body naturally, eliminating up to 15-decibel loss over wearing it in the pocket.

Proper Donning of the Radio Strap

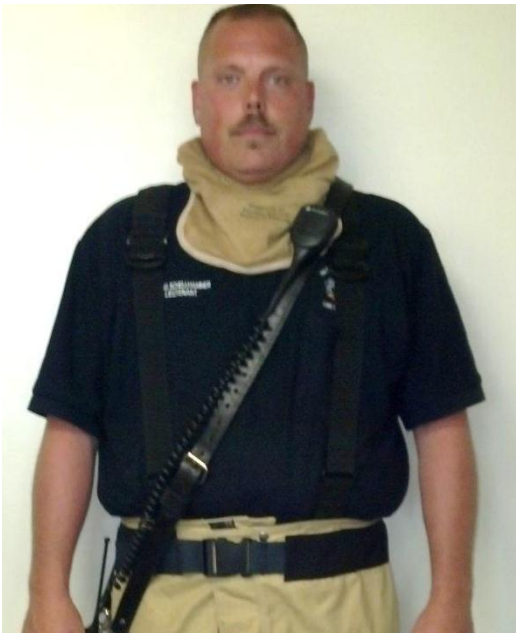


Figure 1 – Don strap either over or below suspenders.

Figure 2 – Don coat, un-clip the RSM and place it to the side, clip all four buckles.

Figure 3 – Affix the entire length of the vertical coat flap. (The RSM shall not be fed through the vertical flap)

Figure 4 – Option 1, let the RSM hang and then affix the collar flap.

Figure 5 – Option 2 – Clip the RSM to the lapel and then affix the collar flap. *Option 3 would be to clip the RSM to a Mic Keeper.*

Proper Donning of the Radio Strap

Figure 6 – The portable radio should hang below the coat line with the antenna canted away from the body. The radio will naturally orient behind the bunker pant pocket.

THERMAL PROTECTION

Thermal protection issues can be classified in two areas for concern: Thermal protection of the radio itself and thermal protection of the Remote Speaker Mic (RSM).

As noted in the NIST, Testing of Portable Radios in the Fire Fighting Environment report, heat can negatively affect the performance of electronic devices in the thermal environment. While the test conducted by NIST was not performed to determine the best practice for carrying the radio in the IDLH, it did reveal gaps in the functionality of equipment firefighters rely on when operating at fires. Through the testing, manufacturers, like Motorola, took the information garnered from the report to improve radio performance in hot environments and produced rugged portable radios with internal and external ergonomic improvements specifically designed for firefighters. Examples can be found in the Motorola APX XE line of portable radios.

During the NIST tests, radios were exposed to heat in two variations: First, a radio was stored in a simulated radio pocket and second, they tested a radio without any protection or carrying harness. Without surprise, the test radios protected by the simulated radio pocket performed slightly longer than the bare, unprotected radios. It is important to note that the test did not include protection of a leather radio pouch, much less a pouch devoid of cut-outs normally found in many leather radio pouches. This is important, as it was not done as a comparison of different carrying ensembles. It is also important to note that in the study, NIST openly discloses that no matter the protection of the radio proper, the RSM and antenna are exposed, which are the weakest link in the system.

> (NIST, 2007) *4. While pocket protected radios withstood Thermal Class III conditions, the cord and speaker/microphone limited their performance to Thermal Class II conditions. Improving the thermal performance of the speaker/microphone and cord could move pocket protected radios to Thermal Class III electronics.*

Additionally, the NIST report also describes a potential for the radio not to work, even if depressing the PTT button on the radio in an attempt to override a malfunctioning or electrically shorted (due to melting) RSM. The numerous stranded and braided wires within the RSM make it unpredictable as to whether the radio body PTT button will override the RSM.

> (NIST, 2007) *Some of the radios operated such that when the external speaker/microphone was connected, it disabled the PTT and speaker on the radio itself, diverting all transmission and reception to the external speaker/microphone. If the external speaker/microphone or its cord were to fail, in an emergency situation it would be extremely difficult (if not impossible) to disconnect the speaker/microphone and operate the radio by itself. Thus failure of the external speaker/microphone, the part most likely to be exposed to extreme conditions, could mean loss of the radio operation entirely.*

The perception that it is easier to depress the radio body PTT button through the radio pocket, as opposed by attempting the same tactic on a radio strap, is not logical. Every attempt should be made to avoid this emergency procedure by protecting the RSM cord.

Thermal protection for the radio itself, while in the IDLH, has several factors associated with it. The reality in the NIST report is that while the radio pocket provided some level of protection, the pocket is not designed with the same thermal protection found on the majority of the coat. That being said, the same level of thermal protection, if not more, can be gained when the radio is covered with leather.

Furthermore, the difference in height, between the radio pocket and radio strap, is 2-feet on most people. The thermal variant in two feet can be significant. While some may argue that two feet may not prove to be significant enough, it is important to understand that heat soaking is progressive, so with that, the longer you minimize the heat exposure, the more time you will have before catastrophic failure in the radio. Gear seized after the fire at Southern Motel clearly distinguishes the thermal charring at radio pocket level, as opposed to pant pocket level where the radio strap would reside.

This same fire resulted in the portable radio RSM melting to one wire. The radio shown (left) was worn in the radio pocket.

The same outcome to the RSM cord is achieved anytime the cord is exposed, whether in the pocket or on a strap outside of the coat. Many times, the result includes activation of the talk-group without input or output sound, similar to an open mic. When this phenomenon occurs, everyone on the fire-ground is precluded from transmitting or receiving relevant audio traffic; to include MAYDAYs or emergency traffic.

The notion that this issue would only affect one firefighter is not correct. A firefighter operating a hand-line in the basement could unknowingly experience melted RSM wiring resulting in a short that creates an open mic situation, jamming fire-ground communications and preventing a firefighter on the second floor conducting a high-risk search from calling a MAYDAY. A similar situation could be a firefighter that falls through the floor, experiences a melted RSM wiring resulting in a short that creates an open mic situation, jamming fire-ground communications and preventing their officer from calling the MAYDAY and getting appropriate resources to the inured firefighter.

Other scenarios include entire companies being affected, as noted in Bladensburg, MD. It simply is not realistic to think each member of the company experiencing a thermal emergency will have the presence of mind to negotiate and trouble shoot a radio stored in the pocket that has experienced a RSM that has melted and shorted out, causing an open mic on the fire-ground tactical channel. After a failed attempt in calling a MAYDAY, their focus is to get out.

These types of rapid fire progression incidents rarely only affect one firefighter; it affects several firefighters and can compound the safety of multiple companies operating remotely from each other.

The goal should be to avoid relying on an emergency procedure (*keying the mic through the radio pocket in an attempt to override a melted RSM*) over protecting the RSM in the first place, thus minimizing the issue of a melted and shorted RSM.

The comprehensive solution is to wear the RSM cord under the coat. DC FEMS is experimenting with a PBI sheath that covers the RSM cord when wearing the strap "over" the coat and it is a good idea; however, the other issues associated with wearing the strap over the coat include: entanglement, less protection than wearing it under the coat, and the antenna does not cant away from the body in the same manner as when you wear the radio strap under the coat, but below the skirt of the coat line; which is critical in reducing signal loss.

RADIO EJECTION

The issue of retaining the portable radio in the radio pocket is not new. Portable radio ejection happens on a regular basis to firefighters conducting fire-ground duties. Whether it is during a search, when firefighters are on their hands and knees or when opening up roofs, either manually with axes or with power saws, the instances of radio ejection occurring at any percentage are unacceptable. It is hard to quantify the actual percentage this occurs, since firefighters often individually deal with the issue and seldom report it to a point where it can be properly documented and statistically calculated.

However, in 2011, Fairfax County Fire & Rescue Department conducted a Firefighter Survival program, which included a Floor Collapse Simulator that over 700-firefighters participated in over a year and a half. In a rare opportunity to trend issues that firefighters encounter while conducting complex tasks or operating in physically challenging environments, facilitators for that program documented a 40% radio ejection rate for firefighters wearing their radio in the radio pocket. A similar prop in Montgomery County, MD yielded an equivalent 40% ejection rate for the radio pocket.

It shouldn't be a hard concept to grasp, as we expect 2"x3" piece of hook and loop to hold in an almost 2-pound portable radio. The environments that firefighters operate expose the hook and loop to extremely challenging conditions. Debris from fires, dust and dirt, and other things like fabric "fuzz" attach the hook and loop; which over time degrade the ability to remain fastened. A company averaging 10-calls a day can expect to open and close the radio pocket flap a minimum of 20-times a day and 2,400 a year. Hook and loop has an average life span of 3,500 applications under ideal conditions.

As noted in the photos on pages 12-13, the reality is that radio pocket flap is rarely applied as designed. This is due in part to several factors to include: interaction of the high pressure SCBA hose, items such as the Thermal Imager that often hangs off of the SCBA shoulder strap, repeated open and close applications required to change talk-groups or adjust volume to avoid feedback from other users transmitting in the vicinity, as well as initial incorrect application.

The Firefighter Survival Program included four critical self-survival techniques resulting from lessons learned at close-calls and LODD reports. In the 1% environment that we're trying to teach survival, there is a 50% chance that the user will have their portable radio. This is an unacceptable statistic.

The natural reaction to the subject of portable radio ejection from the radio pocket is to develop a better connection point; however, the issue of the radio pocket is a multi-faceted problem of retaining the radio, exposure of the vulnerable RSM, and radio signal loss associated with the antenna positioned against the body. Furthermore, an addition of a more secure attachment type will produce additional adverse effects, to the ability to open and close the flap while wearing thick firefighting gloves, such as:

- Change Channels/Talk-groups
    - Important for emergency procedures involving switching channels to the dispatch channels on Alpha and Papa, when the tactical channel is busy, as well as going to the non-repeated Oscar Safety Channel.
- Adjust Volume
    - Critical and done several times during an incident to avoid feedback when another user is transmitting nearby.
- Access to the Emergency Alert (EA) button on the top of the radio.
- Opening the flap while in the IDLH, limited visibility, and/or in the crawling position increases the chances of the radio flap not securing, thus falling out.

Another issue coming to light is the problem of the RSM retainer clip breaking off the head of the mic. This can occur when the RSM cord is snagged and the retainer clip assembly either breaks or slides off. In two recent occasions, this occurred unknowingly to the officer. In one of the two recent occurrences of this issue, the RSM became entangled with the Officer's firefighter in zero-visibility conditions while crawling and trying to stretch a line to the seat of the fire.

When the RSM is worn under the coat and protruding out, the issue of the RSM breaking off will not yield the same disastrous effects; it will simply hang down a few inches.

This photo was taken during training with recruits learning to buddy breath and share air from their SCBA. Because this training occurs in zero-visibility, the firefighter on the right was unable to distinguish the RSM cord with their gloves, thus errantly wrapped the cord around the other firefighter. Note the radio pocket flap is open.

This occurred on an actual fire in the example noted above where the lapel clip broke from the RSM head and wrapped around the officer's firefighter.

RADIO SIGNAL LOSS

The effects of portable radio transmission and reception caused by different portable radio carrying methods can have significant effects on overall public safety radio system performance, particularly for users operating indoors, where signal levels are already attenuated as a result of building penetration losses.

800 MHz public safety radio system technologies are “line of sight” in nature. The best-case scenario of portable radio performance is a direct line of sight path between the portable radio user and the system antennas. Any man-made or naturally occurring obstructions in this path will attenuate the radio signal. The Fairfax County public safety radio system includes significant additional margins built into the system design to help overcome these losses, resulting in a system design that provides reliable indoor portable radio coverage into most occupancies within the County. However, it is important to note that indoor coverage reliability can be affected by a number of factors. Some of these factors are under the control of the end user, and others are not. For example, providing reliable coverage to below grade areas, or areas deep within large occupancies or those of heavy construction can be difficult or impossible. Additionally, large occupancies located in areas of the County where the system building penetration margin is not sufficient to provide reliable coverage inside of large occupancies may also have unreliable indoor coverage, for example, large schools in areas of the County that are primarily residential.

Because this is a line of sight technology, the RF energy to and from a portable radio operating inside of a building behaves much like light. In a very general sense, RF energy enters a building in the same way that light does, through doors, windows, skylights and other openings that are large enough for the RF energy to pass through. For a practical perspective, imagine the interior of a large commercial occupancy on a day with very sunny and bright conditions outside. Now imagine that commercial power to the building is shut down, and that there is no man-made light available inside whatsoever. The areas of the building that are pitch black dark will also be the areas that are most difficult to cover with an 800 MHz radio system. These areas would include rooms and stairwells near the center of the structure, bathrooms, and below grade areas.

RF energy can pass through solid interior and exterior walls, but these structures cause significant attenuation of the RF energy, and can be nearly radio-opaque if made of metal or have imbedded rebar or wire mesh in their construction. Low thermal emissive (Low-E) glass is used in modern construction and contains either a tin oxide or silver film that reduces thermal emissivity and improves energy efficiency of the building. The metal film used in Low-E glass can also have a significant effect on coverage reliability indoors.

System coverage design margins are additional RF design margins included in the design of a radio system that are intended to provide additional signal to penetrate man-made obstructions and structures. These margins provide coverage above and beyond that which is required to communicate with portable radios operating outdoors at street level.

From a system coverage perspective, the best-case portable radio operating scenario is that in which the user is standing and operating the portable radio at head level, with the antenna positioned vertically and clear of body mass or obstruction. Any deviation from this best-case scenario will create additional losses that may or may not impact the ability of the user to communicate, depending on the amount of additional design margin that exists at the user’s specific location. These losses are known as “user coupling losses” and are measured in decibels, or dB. For every 3 dB of loss, radio power is reduced by half. As an example, a portable radio carrying method that creates an additional 9 dB

of loss reduces the effective transmitting power of a 3 watt portable radio by half three times, making the 3 watt portable radio a 0.375 watt portable radio.

Thus, it becomes imperative to have an awareness of various portable radio carrying methods and the effects that these methods may have on signal attenuation. In many cases there are simple things that can be done to minimize attenuation and maximize portable radio performance. For example, television has made popular the technique of holding a portable radio horizontally (aka "gangster style") or even upside down while transmitting. While for some this may seem like a stylish way to operate the radio, it is not a good idea from a radio system performance perspective, since the system antennas are vertically polarized, and transmitting from a horizontally polarized antenna to a vertically polarized antenna can result in 7-15 dB of additional coupling loss.

Different portable radio carrying and operating methods can have a dramatic effect on signal propagation. Vertical vs. horizontal antenna orientation is only one factor. Another key factor is absorption of RF energy by body tissue mass.

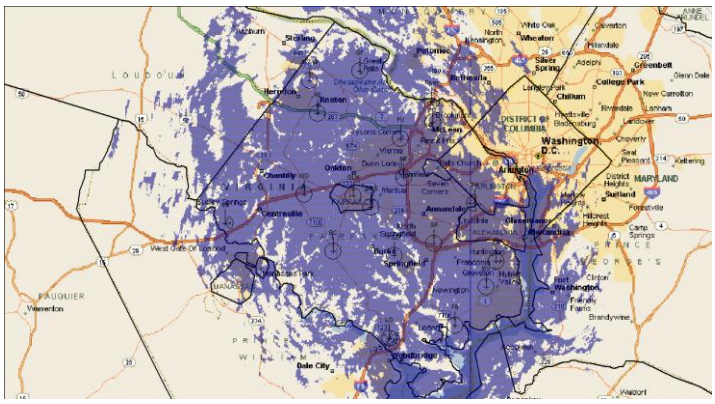
In an effort to better understand the effects of various portable radio carrying methods on signal propagation, the County's radio consultant conducted informal antenna field testing in 2002 with a member of the Fairfax County Sheriff's Office. This testing compared the best-case scenario (antenna vertical at head level) to other portable radio carrying methods to identify the user coupling losses associated with each carrying method and gain a better understanding of how portable radio communications can be adversely impacted by the way a public safety user carries and operates their portable radio. Similar testing was conducted with members of the Fairfax City Fire Department in 2008 to evaluate the user coupling loss impacts of portable radio carrying methods used in fire and rescue operating environments.

Generally, this testing found that the distance between the portable radio antenna and a user's body mass is a critical factor in the impairment of RF propagation from portable radios that are worn or operated with the antenna in close proximity to the body. The closer the antenna is to the body, the more user coupling loss occurs. Carrying and operating methods that mash the antenna against the torso or chest are particularly bad, as are those methods where the radio is attached to a user's belt at waist level, in a location that results in the user's arm being draped over the antenna while the user is standing or seated. Dramatic improvements are possible even with small increases of distance between the portable radio antenna and the user's body mass. At distances of 7-10 inches the effects of RF absorption by body mass become hardly noticeable.

It is clearly understood by system engineers and designers that public safety portable radio users rarely have the luxury of operating their portable radios while standing, with the antenna held perfectly straight. Allowances for user coupling losses are included in system designs along with those to provide margin for building penetration. However, it is important to note that it is really not possible to design a system that can both penetrate a commercial occupancy and overcome the user coupling losses created by the worst-case portable radio carrying methods. Therefore, it is very important to minimize user coupling losses whenever possible, but preferably without asking the public safety end user to sacrifice overall safety and take risks just to accommodate the radio system.

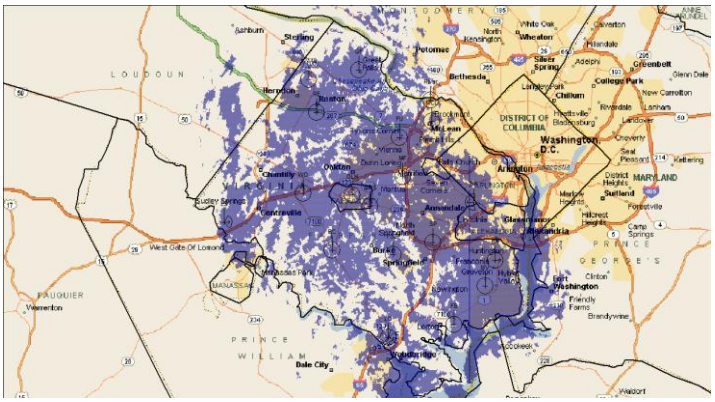
In many cases this comes down to a matter of simple compromise. Given a public safety portable radio end user's requirements for overall safety, what are the portable radio carrying methods that will work? And of these, which is the method that will result in the lowest user coupling losses without impacting the ability of the end user to perform their work in a hazardous environment?

Radio Signal Loss Overlay Comparison



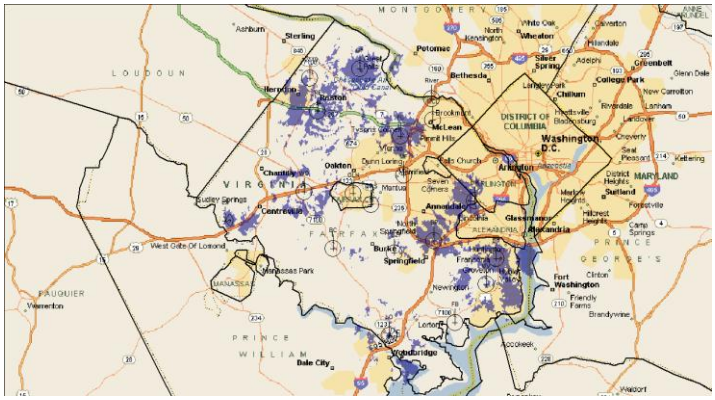
0.0dB LOSS

Optimal 95% Estimated Coverage in SFD



7.0dB LOSS

Strap Under Coat Antenna Exposed—Standing



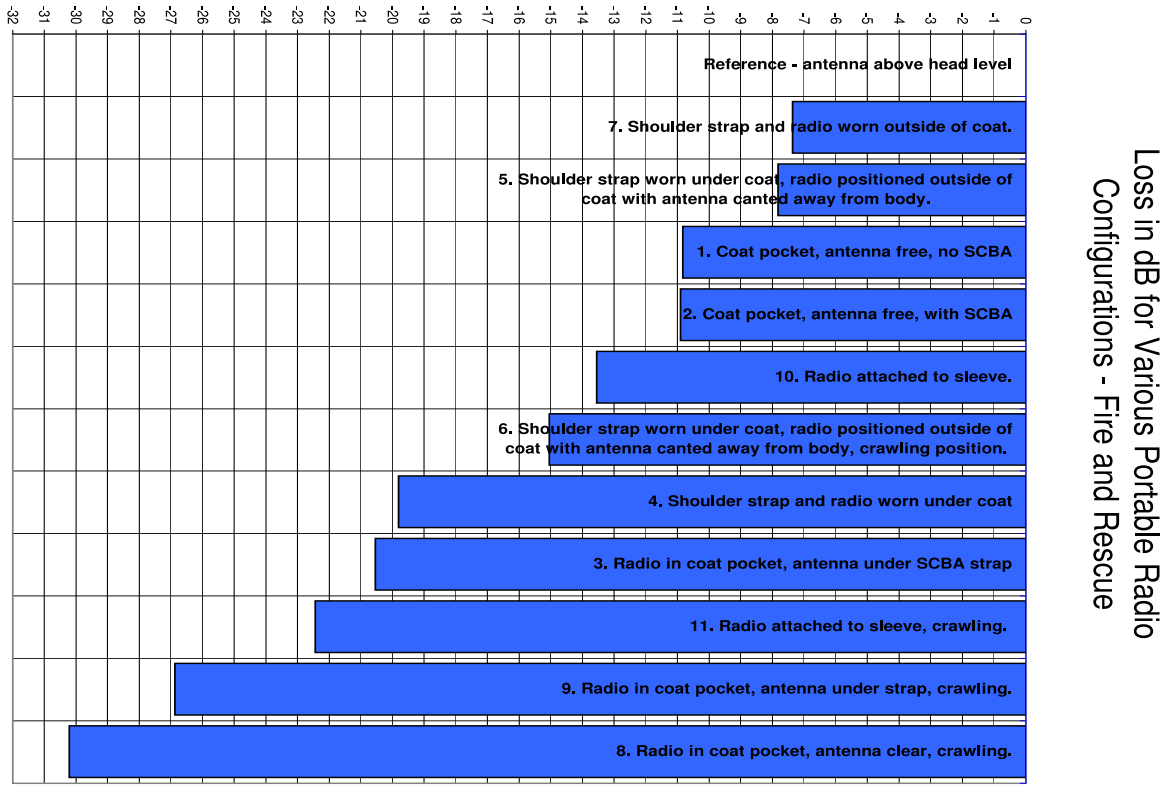
15.0dB LOSS

Strap Under Coat Antenna Exposed—Crawling

30.0dB LOSS

Radio Pocket While Crawling

Radio Pocket—Standing



Loss in dB for Various Portable Radio Configurations - Fire and Rescue

BACKGROUND

In 2009, a policy went into effect regarding the use of Portable Radios in IDLH environments. The document discussed communication failures and classified them into two categories: Equipment-related and Personnel Action-related. In the statement regarding equipment-related communication failures, the document used two studies to support the argument that portable radios should be worn in the radio pocket integrated into the coat of the PPE ensemble.

The two studies referenced in the 2009 policy were the Prince William County Department of Fire & Rescue (PWDFR) *Radio Test Final Report* and the National Institute of Standards and Technology (NIST) Technical Note 1477, *Testing of Portable Radios in a Fire fighting Environment*.

The authors of the GO made two statements regarding the NIST study and the PWCDFR study respectively:

- *"The results revealed that placing the radio inside the turnout coat pocket allows the radio to survive in elevated temperature conditions whereas radios not protected by a turnout gear pocket did not survive these same conditions."*
- *"The Prince William County Fire and Rescue Radio Test Final Report documents that when large amounts of water are applied to the remote speaker microphone and unprotected radio, the audio becomes muffled and the speaker microphone is prone to shorting out and transmitting constantly. When the speaker microphone sticks open, no audio is received by the radio."*

The intent of the two studies was not to regulate the positioning of the radios in the IDLH. The utilization of the two statements fails to factor in numerous other elements that don't support the argument of the policy. Furthermore, recent studies by Fairfax City clearly identify signal loss arguments that suggest that the integrated PPE radio pocket is not the best practice to ensure the ability to transmit.

The PWDFR report was initiated in response to Marsh Overlook Drive fatal fire. The three objectives of the test were:

- Identify strengths and weaknesses of the portable radio and accessories
- Determine the impact of water on the portable radios
- Evaluate the Emergency Activation (EA) function

Extensive testing was conducted with numerous extended microphone types to determine water's effect on radio functionality. While no specific recommendations were given regarding the IDLH carrying of portable radios, two specific Strengths and Weaknesses were noted.

> Strength: (PWCDFR, 2007) *The portables obtain the best signal strength when operated with the antenna in a vertical position.* Likewise, the first bulleted weakness was noted to be: (PWCDFR, 2007) Operating *the radio with the antenna in a horizontal position or covered by heavy clothing/coats will diminish some of the signal strength. While this impedance is not usually noticeable, it could make the difference if you are in a marginal signal strength area.*

The main emphasis of the Prince William report focused on water's effect on the portable radio. Many of the water related issues have been resolved through the purchase of sealed connections and the removal of the attachment screw from the extended mic to the portable radio.

The best practice or recommended location of the portable radio is not included in this document and nothing in this report points to the radio pocket as the safest location for the critical communication tool. In fact, the first bullet in both the strength and weakness mention the dangers of horizontal antenna orientation (usually found while crawling or incapacitated) as well as the danger of a firefighter's body and PPE covering the antenna, thus leading to significant loss in radio power.

It is important to note that while Prince William DFR does not have a formal policy regarding the placement of the radio, their training and recruit schools instruct users to wear their radios in a leather strap, under their coat, but below the coat line with the antenna canted away from the body.

The second document used was the NIST Technical Note 1477, *Testing of Portable Radios in a Fire fighting Environment*. This report was intended to introduce the need to classify electronic equipment in the firefighting environment and require additional thermal protection in production; not prove that the radio pocket protects the portable radios from the effects of heat a fire conditions.

The test was done in a closed loop wind fire tunnel under controlled conditions; however, the test does not account for various other factors critical to the function of a firefighter in real-life conditions. Since the test was done in a 14-inch box, the height difference of 24-inches in relation to the radio pocket, as opposed to a radio strap was not accounted for. Since heat rises, this important element has not been addressed in the survivability of the radio device.

The test also does not factor that the first point of failure is the antenna and extended radio microphone, since both of those elements are not protected by the pocket. They are in fact exposed to the austere conditions. If the antenna melts, it will reduce or incapacitate the ability to transmit. The fact that the radio itself is meagerly protected is irrelevant.

> (NIST, 2007) *4. While pocket protected radios withstood Thermal Class III conditions, the cord and speaker/microphone limited their performance to Thermal Class II conditions. Improving the thermal performance of the speaker/microphone and cord could move pocket protected radios to Thermal Class III electronics.*

Additional factors such as wearing the radio strap under a coat, but cantering out below the coat are not addressed. The obvious advantages of the extended microphone being protected under the coat cannot be overstated.

> (NIST, 2007) *In some cases, the portable radios used in a fire fighting situation would be protected from direct exposure either inside a pocket or worn under the turnout gear.*

Furthermore, positioning the radio strap in the above manner allow for two points of PTT activation. In event that a firefighter is incapacitated on the ground, he or she have access to the PTT on the radio (if their arms are at their side) or near the neck on the extended mic (if the hands are positioned near the face).

The radio strap configuration also allows fire fighters to quickly glance down at the radio to confirm proper channel or zone. When oriented in the radio pocket, the radio must be pulled out and re-inserted. This can be complicated by passport tags or wire cutters which may be co-located in the pocket.

One final physical advantage of the radio strap is that when a firefighter is in the crawling position, the radio naturally remains upright (on a swivel), which gives the antenna proper vertical positioning. This was noted twice in the PWDFR report.

In reaction to the 2009 policy, Fairfax City Fire & EMS conducted several signal loss studies to determine which method of radio storage offered the least amount of loss. Coordinated with a representative from Motorola, Fairfax City conducted tests with the radio positioned in several configurations and determined that the safest and most practical method carrying a radio was using a radio strap, under the coat hanging below the coat line with the antenna canted out. This configuration provided the most amount of thermal protection to the extended mic and significant advantages in reducing radio frequency loss.

Another recent observation was noted during the recent fall 2011 training evolutions. During the maze and floor drop-out evolutions, instructors noted on several occasions that portable radios stored in the coat pocket fell out. In some

cases the radio was completely lost in the simulated debris pile. Again, this was observed at a rate of approximately 40%.

Furthermore, during the same training sessions, numerous portable radios were "snagged" during the bailout evolutions, which included rope bailouts and ladder bailouts.

The last and most compelling argument has come from the Radio Services section of DIT. Jack Anderson, a resident expert in the field of radio frequency, has noted:

> "*…it is very important for all end users to ensure that the radio antenna is unobstructed (or as unobstructed as possible) to ensure the most effective transmission of RF energy from the portable radio to the radio system, and the most effective reception of the radio system at the portable radio. My experience is that there is a dramatic reduction in transmission and reception effectiveness if any part of the portable radio antenna is touching the user's body, with the most dramatic effects occurring when the antenna is touching large body mass areas such as the chest or the torso. This effect becomes less dramatic as the distance between the body and the antenna increases. Even a couple of inches can make a noticeable difference when compared to touching the body. With separations of seven inches or more, the effects are very small. Personally, I prefer to see at least four inches of separation between the antenna and the body, with the antenna positioned as close to vertical as possible."*

The statement is not new, as noted in Jack's 2002 report, *Portable Radio Loss Analysis.* Whether the portable radio is clipped to the belt – as most police officers wear the radio – or worn in a coat pocket, when the antenna is positioned against the user's body, the power of the portable radio is significantly reduced.

The danger of reducing the 3-watt capability of the department's portable radios to 0.01 or less watt capability is in essense reducing the firefighter's chances of calling for help when placed in an emergency. The day-to-day experience may not be noticible; however, when a 0.01-watt radio is operating in a marginal signal area, covered by the body of a face-down firefighter, or in a basement, the ability to call for help over the radio is dramatically reduced, if not impossible. This is not as a result of a system problem, which may not be in our control; rather, the signal loss is produced by a department policy.

It would be the recommendation of the Communications Section to allow a best practice of using a radio strap under the coat with the extended mic hanging over the top buckle of the coat, but protected by the full seal of the hook and loop flap, the radio strap must be long enough to hang below the coat length. It is also recommended that the elastic strap, which is designed to secure the radio in the leather pocket be removed to allow for easy one-handed disconnection of the extended mic and removal of the radio from the pocket.

The protective envelope of the PPE ensemble is virtually sealed by the mandatory use of the SCBA waist strap. The use of the strap under the coat will not change the protective envelope status. Moreover, the use of the extended mic over the top buckle, but sealed between the hook-and-look protective flap, will not change the current status of the seal.

FIREFIGHTER SURVIVAL PROGRAM

Beginning in March 2011, the Fairfax County Fire and Rescue FF Safety and Survival program was developed and has been delivered to nearly 700 firefighters and officers over a 1.5 year span. Each part of the program focuses on different survival situations a firefighter could be involved in which requires them to react quickly and efficiently while concentrating on air management and good communications with command. Below are the observations concerning the current location of the portable radios. These concerns were either relayed by the participants themselves or the instructor leading that particular evolution observed the issues.

#1: Wall Breach/Diminished Clearance (typical wall opening 16" on center and 22" high)
Purpose: In Pre-Flashover conditions, a firefighter must exit the room immediately and most often by breaching a wall to enter into a safer atmosphere before the affected compartment ignites
Task: Properly wearing the SCBA and with the techniques taught, maneuver themselves through the pre-made opening. This is done in a quick and controlled manner.
Findings: Consistently, 4 out of 5 firefighters were getting their radios/radio pockets hung-up on the stud. Tested by the instructors, this hang-up is non-avoidable with the radio in its current position. This results in the firefighter taking entirely too long getting out of the IDLH or they fight through the hang-up and rip their radio pocket causing the radio to fall out and drag behind or completely detach. I personally ran this portion of the program and can say first hand that the only individuals not having issue with the radio pockets were people with smaller than average stature.

#2: Entanglement (Hanging wires of different gauges)
Purpose: When the firefighter is caught in a collapse whether full or partial, they have to deal with a number of different obstacles, one of them being wires/cables. The firefighter must be able to negotiate this obstacle quickly while avoiding any entanglement.
Task: While following a charged hose-line the firefighter after determining the way out of the structure will need to successfully deal with an entanglement either through the swim technique or cutting the wires with their own pair of cutters.
Findings: It was observed that almost every firefighter when coming in contact with wires, laid on the floor with their SCBA cylinder in the corner of the wall and floor. This happened no matter if they were preparing to cut the wires or using the swim technique. The issue arose when we started noticing that the radio/radio pocket then became the most vulnerable point for wires to become tangled on. The issue was not getting the wires off the radio, it was when the firefighter chooses to cut the wires, and they were unable to differentiate between the entanglement wires and the radio wires.

#3: Floor Collapse (Collapse prop with a drop of 3-4' into foam blocks)
Purpose: Firefighters cannot prepare 100% for every mayday incident. Exposing them to as many as training incidents as possible will give them a skill set and determination of how they will react and communicate in a survival situation, especially a collapse situation.
Task: Follow a tagline leading out of the structure. Once the firefighter is over the collapse pit, the floor gives way without warning.
Findings: When a firefighter places their radio in the front pocket, there are a number of factors (poor Velcro, items in the pocket) that may cause the radio to not sit secure with the velcro in place. It was found that approx. 40% or 2 out of every 5 firefighters were losing their radio when falling into the foam from 3'. The mic clip would stay attached only part of the time and most times not. The radio was then un-salvageable by the firefighter in turn losing all communications.



#4: Emergency Ladder Bailout (head first ladder bailout from a 2 story window.)
Purpose: The main focus for throwing ladders at a structure fire is for firefighter egress. This is known and anticipated that when having to exit a structure, attempt to locate a window and if a ladder is present use it. Training for a head first ladder bail in essential for successful egress.
Task: Enter a smoke filled room, find the window and perform a controlled head first ladder bailout.
Findings: When a firefighter performs egress via ladder as a result of a survival situation, it is a reaction not a slow thought process. In training, firefighters were reaching the window finding the ladder and sliding their body onto the ladder over the sill simply reacting to the situation. This was all proper form and technique however each and every time, the radio and handlight (if present) was catching on either the window sill or rung of the ladder. The radio pocket immediately ripped or the velcro came open and the radio fell to the ground. Another concern was that it threw the firefighter off balance when it caught. We began to teach the personnel to press their body over the sill and continue to press up on the way down so their chest stayed off the ladder. Two issues with these teachings: 1) in the emergency setting it is highly unlikely the firefighter will be able to remember this step and 2) Most do not possess the upper body strength to overcome this issue.

CONCLUSION

Firefighter Safety and Communications is synonymous. The ability to have reliable communications on the fire-ground is critical to the safety of the firefighters operating in the IDLH. Dependable communications can save a firefighter's life or prevent a bad situation from getting worse.

Although the Radio Pocket has been integral to the bunker coats for many years, recent hard looks and analysis have proved that there are significant dangers associated with using the radio pocket. Whether it is signal loss from the antenna being too close to the body or the inability for the closure to keep the radio in the pocket or exposure of the Remote Speaker Mic to thermal insult potentially locking the tactical channel from everyone on the fire-ground, it is clear that just one of the negative factors is too much risk for our firefighters. Having all three major factors endangers our firefighters to an exponentially high level.

The negative results from the Radio Pocket are clearly identified and proven. Any concerns about the viability of the recommended best practice of wearing the portable radio RSM under the coat, but hanging the radio below the coat line with the antenna canted away from the body would be purely speculation. A recent close call fire where a fire officer fell through the 2nd floor onto the first floor, prove that in a real-life dynamic fall, the radio stayed in place, as he was wearing it under the coat. Wearing the radio in this fashion is not new and no direct connection to this manner of carrying radios has produced a negative effect, as evidenced by the numerous safety issues experienced with the radio pocket.

Entanglement issues are eliminated, Radio signal loss is improved, the RSM is protected, and access to the controls is at hand. The ability to disconnect the RSM, if practical, is still there and arguably easier. An attempt to bypass a damaged RSM by depressing the PTT button on the radio itself is still available by tilting the radio up and talking down to the portable.

There is simply no valid reason to object to the practice that has been identified. In fact, with the identified critical safety issues associated with the radio pocket, beyond the potential of injury or death to firefighter, the opportunity to litigious liability is too great. There is no way to avoid the liability of such an obvious safety issue.

By committing to sounding the alarms against the Bunker Gear Radio Pocket, the safety for firefighters is increased not only for an individual user, but the entire fire-ground.