Fire
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# Fire Shelters Weaken Transmissions From Hand-Held Radios

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Firefighters who have deployed fire shelters during training have had difficulty communicating using hand-held radios. The Missoula Technology and Development Center (MTDC) conducted a brief study to determine how well radios worked inside fire shelters.

The study showed that when firefighters were inside fire shelters within 50 feet of each other they could communicate using the VHF (Very High Frequency, 30 to 300 MHz) Bendix-King radios. They could not communicate using the newer UHF (Ultra High Frequency, 300 to 3,000 MHz) Motorola Astro XTS 3000 radios. In either case, the radio signals were significantly weaker when the radio (figure 1) was used inside the fire shelter, particularly when the radio was inside the New Generation Fire Shelter.

Essentially, firefighters could shout and be heard as far as if they used their new UHF radios inside a fire shelter. Firefighters probably won't be able to make effective use of their hand-held radios when they are trapped inside their fire shelters. Once the fire has passed, and it's safe to leave the shelter, firefighters can use their hand-held radios to establish communications with each other and with their supervisors.

Figure 1—The newer UHF Motorola Astro XTS 3000 radio (left) and the VHF Bendix-King radio. Both radios have "rubber duck" antennas.

## Study Details

Various factors influence how effective radio communications will be from inside a fire shelter. Those factors include the location of the fire shelter relative to the radio receiving the signals, the location of the radio inside the shelter, the orientation of the antenna, and the fire shelter model. MTDC also looked at different types of radios and antennas.

For the tests, a ¼-wave vertical whip antenna was used to receive VHF signals at 168 MHz. A log-periodic Yagi antenna was used to receive UHF signals at 870 MHz. The strengths of VHF and UHF signals were measured on a Rohde and Schwartz FSH3 spectrum analyzer (figure 2).

Signal strengths were measured in decibels (dB) and decibels referenced to 1 milliwatt of power (dBm). See the decibel refresher section below for further explanation of these units of measure. Although the

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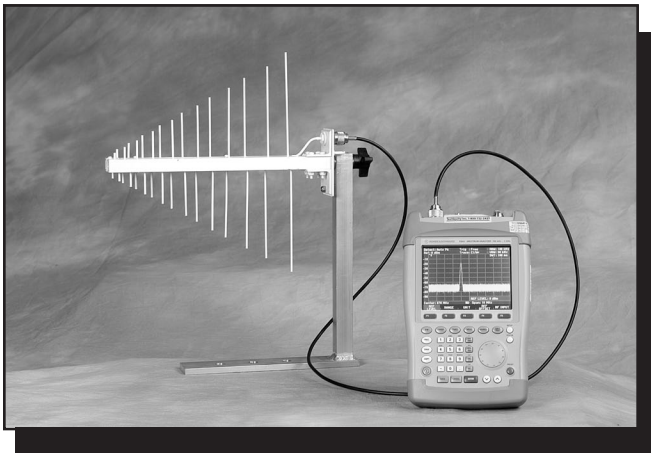

Figure 2—The log periodic Yagi antenna (left) and a spectrum analyzer were used to determine signal strength from the UHF Motorola hand-held radio.

UHF signals were about 5 dB stronger than the VHF signals because of the different types of antennas used to receive the two signals, relative difference in signal strengths did not depend on the type of antenna that was used. The spectrum analyzer and antennas were placed 50 feet from the fire shelters or other radio transmission points. The weather was clear and sunny with a temperature of about 60 degrees F.

The VHF radios tested were Bendix-King GPH5102X models set for 2 watts (W) of RF (radio frequency) output. The antennas were 6-in helical "rubber ducks." The UHF radios tested were Motorola Astro XTS 3000 models with 3 W of RF output. The receiver sensitivity specifications were similar for both types of radios, about 0.3 microvolt (μV) for intelligible reception.

For one test, a fire shelter was aligned with the path to the receiver. An individual inside the fire shelter positioned himself with his head at the end of the shelter nearest to the receiver. His feet were at the other end. He first held the radio 6 inches from the end of the shelter nearest to the receiver and then held the radio in the shelter's center.

The radio was tested at three antenna angles: vertical, 45 degrees, and horizontal in the plane perpendicular to a line to the receiving antenna. Although antenna polarization can be a major factor in signal reception at VHF frequencies and above, the aluminized surface of the fire shelter appeared to alter the polarization of the signal so that the receiving radio's orientation wasn't critical.

An FSH3 spectrum analyzer with a 160 MHz ¼-wave antenna 50 ft from the center of a fire shelter was used to test the VHF Bendix-King GPH5102x radios (set for 2 W output at 168 MHz). The same analyzer with an 800 to 2,000 MHz log-periodic Yagi antenna 50 ft from the center of a fire shelter was used to test the UHF Motorola Astro XTS 3000 radio (3 W output at 870 MHz).

During the tests (table 1), the received signals varied by several decibels because the radio's position was adjusted inside the shelter. Therefore, the values in the table should be considered approximate, within several decibels per milliwatt of the precise values for the specified test conditions. The accumulated signal strengths from three radio orientations in two locations within the shelters were averaged to show the attenuation (reduction of strength) more accurately.

Based on the averages for each test setup, the attenuation of radio signals transmitted from inside fire shelters was as follows:

- Old shelter model with a VHF radio: –33 dB
- Old shelter model with a UHF radio: –43 dB
- New Generation Fire Shelter with a VHF radio: –37 dB
- New Generation Fire Shelter with a UHF radio: –47 dB

Firefighters inside fire shelters also have difficulty communicating over the radio to other firefighters inside fire shelters. Another test was conducted to study this problem.

An individual positioned himself inside an old shelter model. Another individual was in a New Generation Fire Shelter about 50 ft away. Communication was possible with the VHF radios, but not with the UHF radios. According to the averaged signal strength measurements, shelter-to-shelter signals for UHF radios would be –20 dB weaker than VHF signals. This test indicates that communication from inside the New Generation Fire Shelter is more difficult than communications from inside the standard shelter.

Some firefighters have questioned whether they might risk damaging their retinas if they use their hand-held radio inside a fire shelter. The risk of using the radio inside the shelter is essentially the same as that of

Table 1—Test results showing how much transmissions from the VHF Bendix King and UHF Motorola Astro hand-held radios were weakened when the radios were used inside fire shelters. All values are in decibels. The radios were held vertical, 45 degrees from vertical, or horizontal.

| | Radio type and antenna orientation | | | | | |
|---|---|---|---|---|---|---|
| | VHF vertical | VHF 45 degrees | VHF horizontal | UHF vertical | UHF 45 degrees | UHF horizontal |
| **Shelter** | | | | | | |
| Old shelter-center | 47 | 44 | 44 | 58 | 59 | 59 |
| Old shelter-end | 63 | 59 | 63 | 58 | 59 | 65 |
| New shelter-center | 55 | 59 | 55 | 66 | 63 | 77 |
| New shelter-end | 60 | 58 | 57 | 60 | 58 | 63 |
| **No shelter** | 20 | 22 | 20 | 10 | 16 | 25 |
| **Signal attenuation relative to no shelter** | | | | | | |
| Old shelter-center | –27 | –22 | –24 | –48 | –43 | –34 |
| Old shelter-end | –43 | –37 | –43 | –48 | –43 | –40 |
| New shelter-center | –35 | –37 | –35 | –56 | –47 | –52 |
| New shelter-end | –40 | –36 | –37 | –50 | –42 | –38 |

using the radio elsewhere—negligible. The hand-held radios operate at such low power that the risk is essentially eliminated. The limited amount of energy that is reflected from the inner surface of the shelter to a firefighter's head would be much less significant than the energy transmitted from the antenna when the radio is held in front of a firefighter's face. So, even though hand-held radios don't work very well when they're used inside a fire shelter, they don't present a risk to firefighters who try to use them there.

## A Decibel Refresher

Radio technicians and engineers work extensively with signal strengths measured in decibels because they can represent extremely large or small values with two- or three-digit numbers. Decibels work on a logarithmic principle. When working with signal power, the value of a power gain or loss in a system is 10 times the logarithm of that gain or loss. For example, a system with a power gain of 100 would have a gain in decibels of 10 times the log of 100, or 10 • 2 = 20 dB. The log of 100 is two because $10^2 = 100$. Similarly, a circuit whose output is $^1/_{1,000}$ the input power has a gain in decibels of 10 • (–3) = –30 dB. The log of $^1/_{1,000}$ or .001 is –3 because $10^{-3} = .001$.

At radio frequencies in the UHF region (300 to 3,000 MHz), signal power detected from a transmitter decreases by a factor of $^1/_4$, or –6 dB, every time the distance to the transmitter doubles. Increasing the distance 10 times results in a received power loss of $^1/_{100}$, or –20 dB.

This information refers to relative changes in signal strength. It does not describe the signal power being transmitted or received. When absolute power information is required, the unit found most often in communications work is the dBm, or decibels referenced to 1 milliwatt of signal power. A transmitter with an output power of 2 W would provide a signal strength of 33 dBm at its antenna. Good VHF receivers can detect signals in the range of –107 dBm with quarter-wave antennas; "rubber duck" antennas reduce signal detection to the range of –103 dBm.

## About the Author

**Ted Etter** joined MTDC in 2002 to work on electronics projects. He has spent more than 25 years working in the areas of electronic instrumentation and display technology. He received a bachelor's degree in mathematics from the University of Oregon in 1992 and a master's degree in teacher's education from Eastern Oregon State University in 1993. Before coming to MTDC, he taught courses in programming, digital circuits, data communications, radio frequency communications, robotics, microprocessors, and operating systems at the University of Montana College of Technology.

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Wildland firefighters who try to use their hand-held radios inside fire shelters will be unlikely to communicate with their supervisors and may not even be able to communicate with other firefighters inside fire shelters just 50 feet away. Transmissions from the older VHF (very high frequency, 30 to 300 MHz) Bendix-King radios were not weakened as badly as those from the newer UHF (ultra high frequency, 300 to 3,000 MHz) Motorola Astro XTS 3000 radios. The standard fire shelter being carried by wildland firefighters did not weaken the transmissions as much as the New Generation Fire Shelter that is just beginning to be carried by wildland firefighters. The tech tip includes a table showing exactly how much the transmissions were weakened in different situations. Essentially, firefighters could shout and be heard as far as if they used their new UHF radios inside a fire shelter.

Keywords: Bendix-King, communications, equipment evaluations, Motorola

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