Empirical Study of the Effects of 434 MHz *vs*. 915 MHz Frequency Band on the Performance of the Recon Scout

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Abstract

The Recon Scout™ is a miniature robotic platform with applications in civilian law enforcement, emergency response, and critical infrastructure protection. Designed to be thrown into potentially hazardous situations, the Recon Scout must be lightweight and durable. It provides critical video and other sensory feedback to help preserve the lives of responders, suspects, and bystanders. Use of an appropriate frequency band is critical to successful operation. Stringent weight limits require appropriate tradeoffs in operational lifetime, range, antenna size, and motion. In order to optimize the performance of the Recon Scout in real world applications, frequencies in or near the proposed 430-450 MHz range are needed.

1. The Recon Scout

The Recon Scout™ was originally developed at the University of Minnesota under DARPA funding as a miniature reconnaissance platform for battlefield operation. Shown in Figure 1, the Recon Scout is a two wheeled cylindrical robot equipped with a low-light sensitive camera system. The size and weight of the Recon Scout are similar to other throwable gear that a police officer may be equipped with in tactical situations, such as flash, smoke, or gas grenades. Unlike other throwable equipment, the Recon Scout is designed to be reusable, thus it is required to survive regular deployments that involve a 9 m drop onto concrete. Table 1 provides an overview of the operational and functional characteristics of the Recon Scout.

Figure 1: Recon Scout.

Table 1: Specifications of the Recon Scout.

Performance		
Range (Line of Sight)	300 ft	91 m
Range (Non Line of Sight)	100 ft	30 m
Speed	1 ft/s	0.3 m/s
Drop Shock Resistance (vertical)	30 ft	9.1 m
Throw Shock Resistance (horizontal)	120 ft	31.4 m
Mechanical Specifications		
Length	7.375 in	187 mm
Shell Diameter	1.5 in	38 mm
Wheel Diameter	3 in	76 mm
Weight	1.2 lb	540 g
Sensing Capabilities		
Low Light B/W Camera	Sensitivity: 0.0003 lux	
	Field of View: 60º	
	Framerate: 30 fps	
IR Illuminator	Allows operation in zero ambient light.	Optional
Audio	Planned	Optional
Chemical Agent Detection	Planned	Optional
Thermal Imaging	Planned	Optional

2. Need for Effective Range and Building Penetration

Once thrown into a building, the Recon Scout may be maneuvered through several rooms or down flights of stairs in order to find hostiles, hostages, or bystanders. It thus needs the capability to transmit a video signal through multiple walls.

A tactical team can safely employ non-lethal methods only if has time to switch to lethal equipment if necessary. According to Los Angeles Sherriff's Department Commander Charles "Sid" Heal,

> "[T]wenty-one feet [6.4 m] and a hundred and eighty feet [55 m] are the two figures your non-lethal weapon has to satisfy. Twenty-one feet is the distance at which you can be killed by a person with an edged weapon or club if the force you use to deter him is not immediately effective, which means right-now lethal. A hundred and eighty feet – less than three per cent of the population can throw an object large enough to cause serious injury beyond that… If you have a weapon that has a range shorter than a hundred and eighty feet, while you're approaching them to get into your range you're being pummeled with bricks and bottles." [1]

If a suspect is threatening an officer from inside a building, the Recon Scout must have sufficient range to transmit from inside the building [55 meters or 185 feet, according to Commander Heal], plus the ability to penetrate through several walls. An inadequate range means the officers must work in too close and thereby put themselves at risk.

3. Effects of Frequency on Video Performance

To illustrate the effects of frequency on the performance of the Recon Scout, experiments were conducted using two Recon Scouts and Operator Control Units (OCU).

One Recon Scout was equipped with a transmitter in the desired 430-450 MHz range. The other Recon Scout was equipped with a transmitter in the 915 MHz range. Both used an average power of 0.25 Watts. Each Scout is equipped with a ¼ wave, unity antenna. Placing larger or directional antennas on the Scout is not feasible as they can limit movement, impair throwing, and the operator may not know how or where the Scout lands.

Each OCU is equipped with a receiver tuned to the appropriate frequency. For empirical testing, the 434 MHz OCU has a ¼ wave unity gain receive antenna, while the 915 MHz OCU has a ½ wave receive antenna which provides 3 dB of gain. The larger antenna was allowed for the 915 MHz OCU as the ½ wave antenna size is similar to the 434 MHz antenna and was deemed to be functionally equivalent from a usage perspective. For analytic testing a Rohde & Schwarz FSH3 Spectrum Analyzer is used. The analyzer has an effective range from 100 kHz – 3GHz. Scans were done with a 20 dBm reference level starting from 400 MHz to 950 MHz. RBW and VBW were set to 1 MHz with a 100

ms sweep time. Each reading listed was an average of 5 readings. In order to facilitate a fair comparison on the spectrum analyzer, it is used with a ¼ wave unity gain antenna tuned to 434 MHz for the 430-450 MHz tests (Laird model EXC-420-BNX) and a ¼ wave unity gain 902 MHz antenna was used for the 915 MHz testing (Laird model EXC-902-BNX).

Testing was conducted in the lower level of the St. Victoria Catholic Church, located in Victoria, MN. This site was selected for structural purposes. The outer walls were poured concrete, inner rooms were built of either cinderblocks or metal studs. Along the east wall there were no windows which helped to reduce potential sources of multipath propagation. This type of construction is common in both commercial and residential areas and could be regarded as a reasonably typical usage environment.

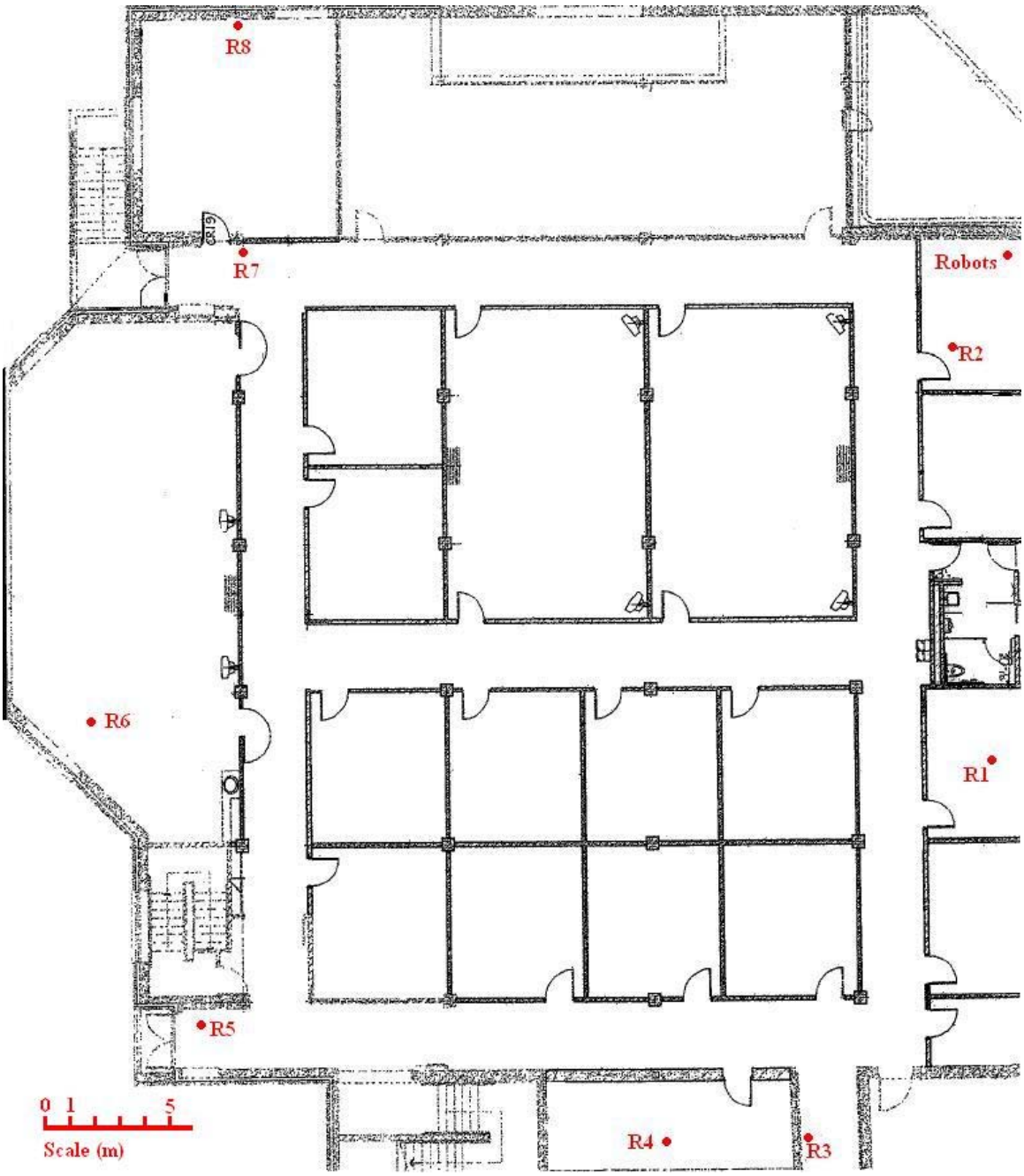

Figure 2: Map of the environment, red dots indicate testing locations.

Figure 2 shows a map of the environment. During testing, all doors to rooms were kept closed, but doors in the hallways were open. The robots were placed in the location marked "Robots" in red, and readings were taken at the red dots labeled R1 through R8.

Sample images were captured using a laptop interfaced to the OCUs to generalize the types of images associated with the testing. Even imperfect images may still be useable. A 5 point scale was devised with 5 – Excellent, 4 – Good (slight interference), 3 – Fair, 2 – Barely Useable, 1 – Totally Unusable. Sample images were made on the 915 MHz

OCU with an antenna that provided an additional 3dB gain over the 434 MHz OCU. These are shown in Figure 3 through Figure 7.

Figure 3: Excellent image, or a 5 on the subjective scale.

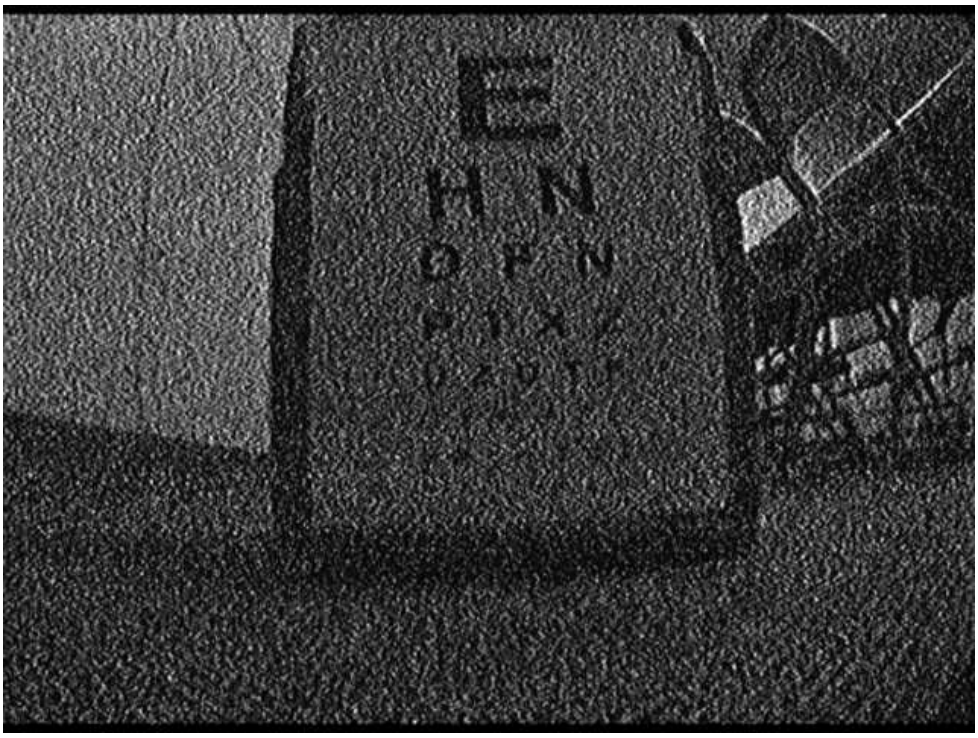

Figure 4: Good image, or a 4 on the subjective rating scale.

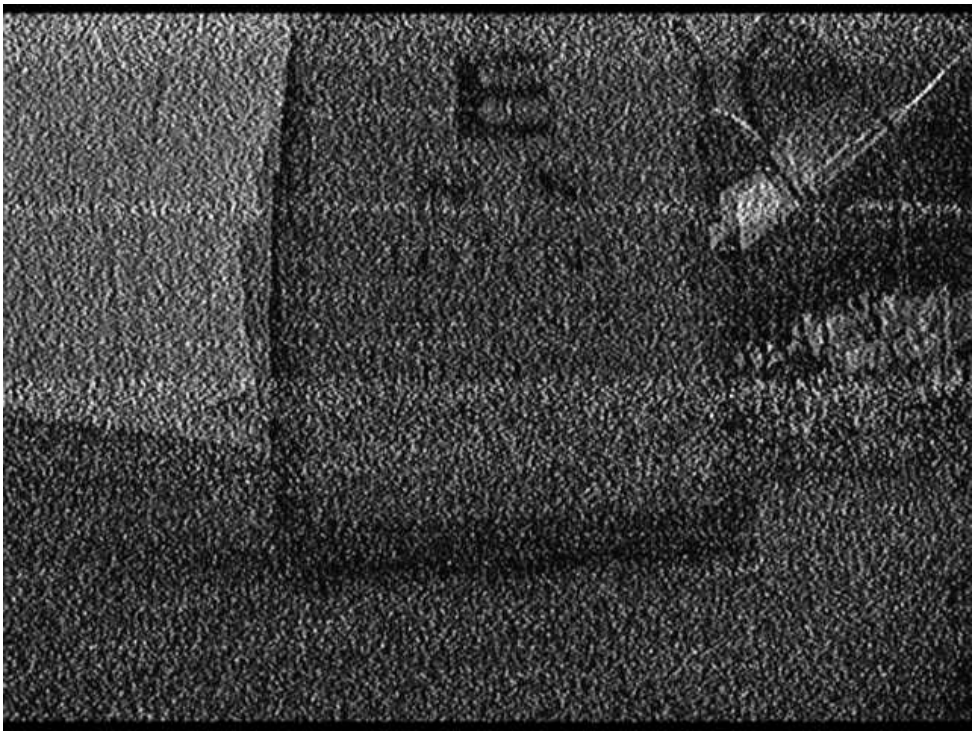

Figure 5: Poor image, or a 3 on the subjective rating scale.

Figure 6: Barely useable image, or a 2 on the subjective rating scale.

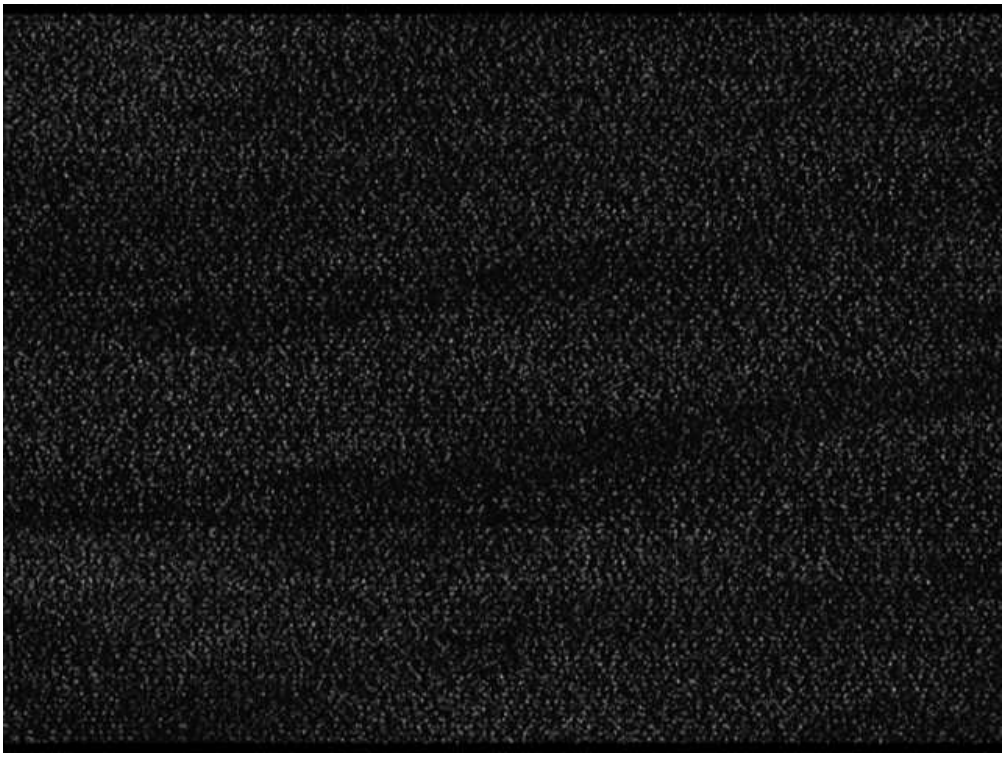

Figure 7: Unusable image, or a 1 on the subjective rating scale.

Table 2 provides the readings from the spectrum analyzer along with the subjective rating of the video quality in each of the 8 positions. The distance is the approximate linear distance between the source Recon Scouts and the OCU. Images of the OCUs were also taken in each of the positions (R1 through R8) and are shown in Figure 8 through Figure 15. Note that in each of these pictures, the 434 MHz OCU is on the right.

Table 2: Readings from Spectrum Analyzer and Subjective Ratings of Video

Location	Apx Distance (m)	# of Walls	434 MHz Reading	434 MHz Rating	915 MHz Reading	915 MHz Rating
R2	3.4	0	-24 dBm	5	-27 dBm	4
R1	18.3	3	-51 dBm	5	-59 dBm	3
R7	26.8	1	-67 dBm	4	-65 dBm	5
R8	29.2	3	-72 dBm	3	-82 dBm	2
R3	33.3	5	-71 dBm	4	-80 dBm	1
R4	34.5	6	-72 dBm	2	-78 dBm	1
R6	37.7	6	-55 dBm	4	-63 dBm	1
R5	39.6	9	-59 dBm	5	-74 dBm	4

Figure 8: Image taken from Position R1.

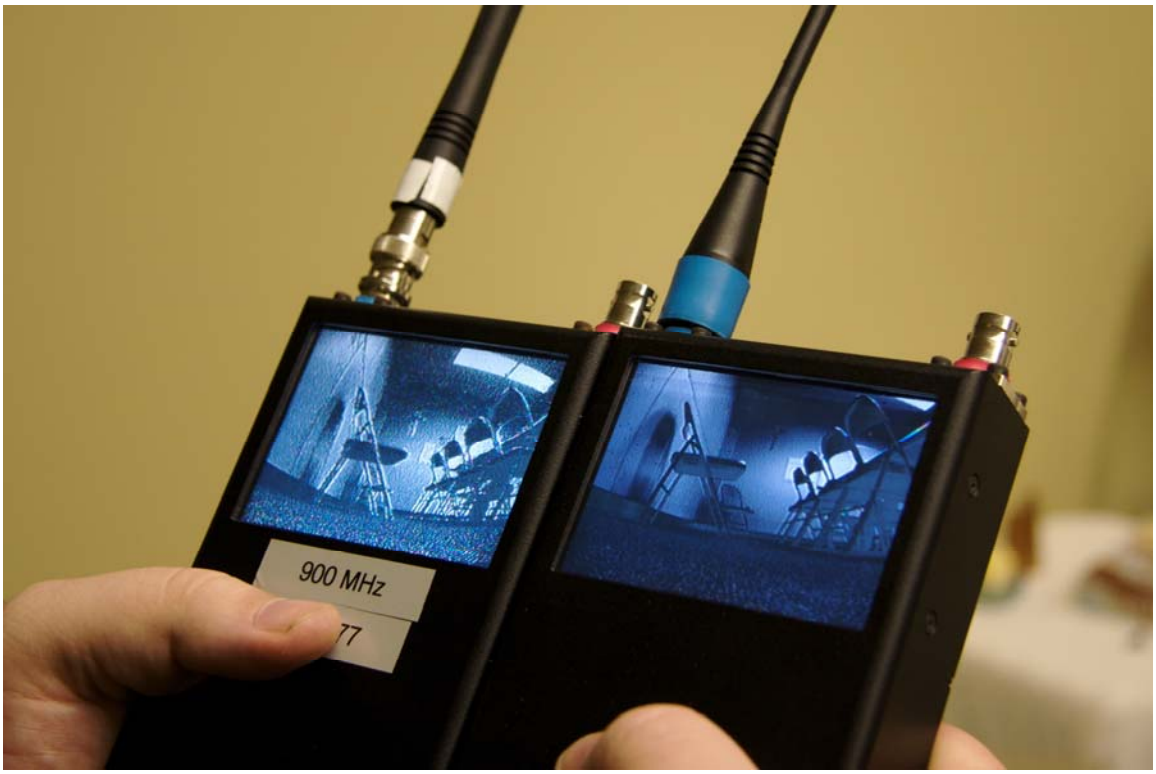

Figure 9: Image taken from Position R2.

Figure 10: Image taken from Position R3.

Figure 11: Image taken from Position R4.

Figure 12: Image taken from Position R5.

Figure 13: Image taken from Position R6.

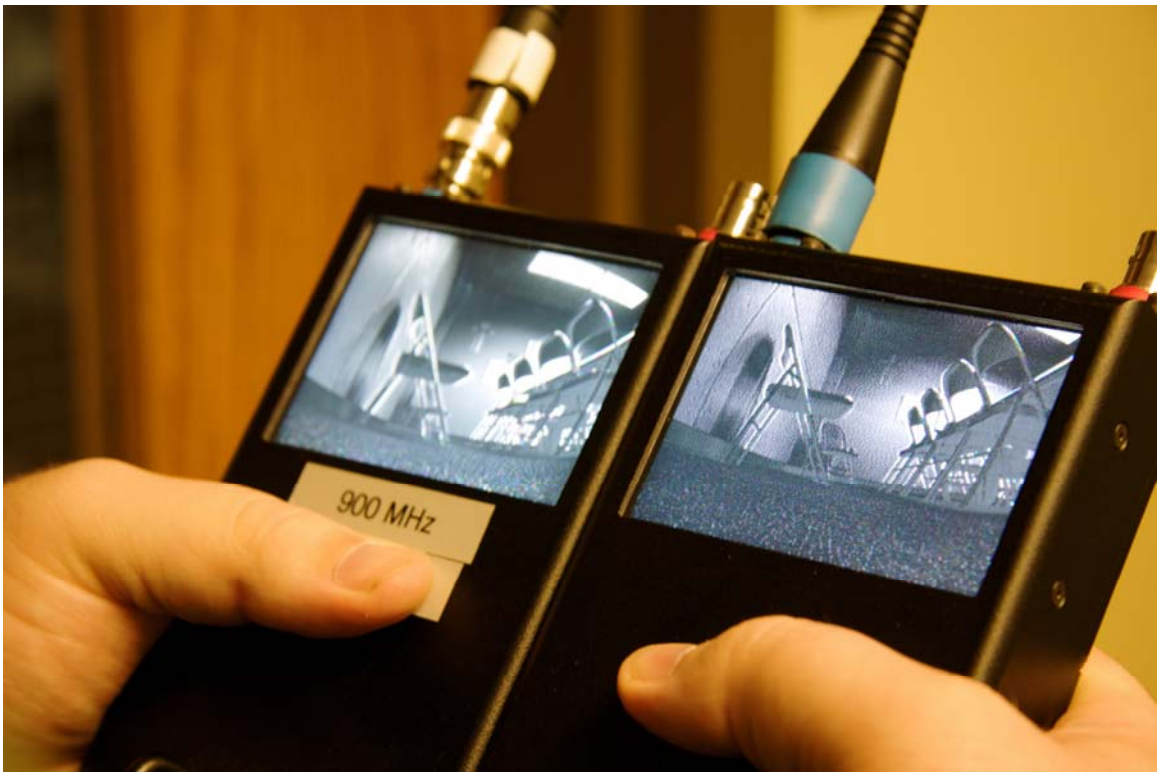

Figure 14: Image taken from Position R7.

Figure 15: Image taken from Position R8.

3. Summary of Observations

The 434 MHz device maintains usable video over substantially greater distances and through several more walls than does the 915 MHz version.

4. Conclusions

In order for the Recon Scout to be effective for law enforcement and emergency response, the device must provide enough operational range and penetration to provide critical intelligence in missions that might otherwise put the operators at risk. Based upon the observed results, the 434 MHz version provides significantly better range and building penetration and is more likely to meet the needs of first responders.

References

[1] Alec Wilkinson. Non-Lethal Force: Looking for ways to stop violent criminals, without killing them. *The New Yorker*, Pages 26-33, 2 June 2008.