FIELD TESTING OF LED SIGNALS

Introduction

In the laboratory environment, the light output of a signal is determined by measuring the luminous intensity and chromaticity; however, the visible range of a signal should ultimately be measured in a field testing environment. Green and Milanovic (2002) helped to develop the Transport Canada standard for highway/railway crossing signals in Canada. As a part of this study, field testing was done to compare the visibility of four pairs of LED signals and traditional incandescent signals. The intensities and beam patterns of the LED signals were first characterized in a laboratory environment. The luminous intensity of the four signals ranged from 300 to 800 candela. The field test was conducted at a former military firing range in Victoria, British Columbia. The signals were mounted to five sawhorses in front of the targets. The field testing set-up is shown in Figure 85. LED signals were placed in Lanes 1, 2, 4, and 5 and traditional incandescent signals were located in Lane 3. A focus group of eleven individuals evaluated the five pairs of signals simultaneously on a clear day. The signals were ranked on a scale of 0 to 10. A 10 was given to the most conspicuous signal, and the remaining signals were ranked in comparison to this signal. The group evaluated the signals at several observation points located between 50 yards and 1000 yards away from the signals. The test was repeated at night with only six evaluators. All four LED signals performed better than the traditional incandescent signals; however, the improved performance was less evident at night. Two more field tests were conducted using newer incandescent lamps and improved test stands. These tests also showed that LED signals performed better than traditional incandescent signals.

Figure 85. Field testing set-up of signal lights (Green and Milanovic, 2002).

The field testing conducted for Transport Canada compared fully-illuminated LED warning signals to traditional incandescent signals. At the University of Alabama, laboratory testing has been conducted to measure the luminosity and chromaticity of LED signals experiencing partial failures; however, no field testing has been conducted to determine the how partially-illuminated signals are interpreted by automotive drivers or train crews. The objective of this project was to develop a field test procedure that can be used to describe how individuals perceive warning signals in partial failure. This included the design and construction of two test stands, a manual switch system to select patterns of non-illuminated LEDs, and the test procedure. Four field tests were conducted with volunteers to determine the efficacy of the field test procedure.

System Design

The procedure for testing individuals' perception of the LED lights was approved by the Institutional Review Board (IRB) at the University of Alabama. The field trial procedure consisted of two tests, a simple eye exam and the LED perception test. Volunteers were recruited from the faculty, staff, students and friends of students in the Department of Mechanical Engineering at The University of Alabama. After the volunteers gave their informed consent, they were given a simple eye chart vision test called "The E-game", which gives approximate visual acuity.

The volunteers were tested “as is” in that they were not prepared in any way, to better reflect their normal vision. They were also asked to wear their usual eyeglasses or contacts as recorded on their driver’s license. The field test must be conducted in a large flat open area with an unobstructed line of sight of 1600 feet. Palmore Park, a Tuscaloosa Parks and Recreation Association (PARA) facility was used for this experiment. The equipment for the test includes two test stands, which each housed two LED warning signals. A description of the test is provided following a description of the test equipment.

Two stands, shown in Figure 86, were constructed to encase two LED signals eight feet high. A manually operated switch system was designed and built to create different failure patterns. The stands also used their own power source (12 volt battery) to operate the lights.

Figure 86. Signal housing with stand.

The manually operated switch system was laid out on aluminum plates, as shown in Figure 87. Double-pole single-throw switches were placed through the holes. A total of sixty-two switches were used to operate the failure patterns. Each light used a different number amount of switches to activate different failure patterns. The signals NPS #4, WPS #2, WPS #3, and NPS #1 were used in field testing, as shown in Figure 88.

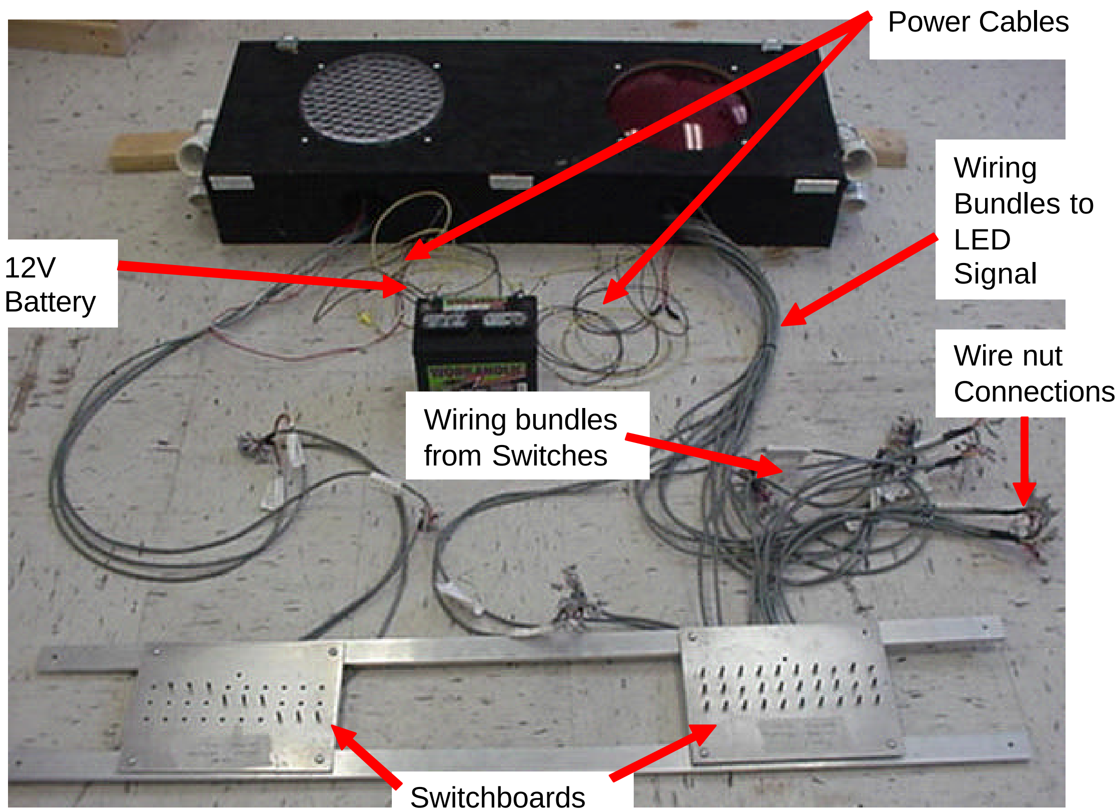

Figure 87. Complete Signal Wiring.

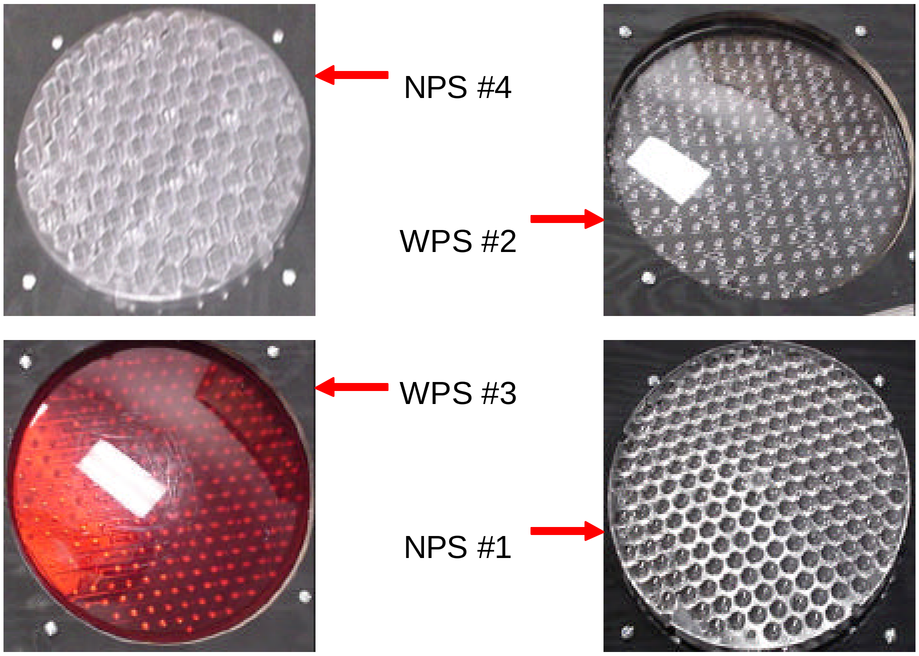

Figure 88. LED warning signals used in field testing.

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All equipment was set up at the field test site well before the testing began, and the stations were pre-marked for the volunteers. Stations were located at distances of 100, 450, 800, 1150 and 1500 feet as shown in Figure 89. Also, for each different test group a pre-arranged test was devised which had specific LED failure patterns for each individual signal to be shown at each observation station. These failure patterns are illustrated in Appendix #. Two pairs of LED signals were located approximately 1600 feet apart facing each other. Each signal was designated by a number to aid the volunteers in differentiating between the signal lights.

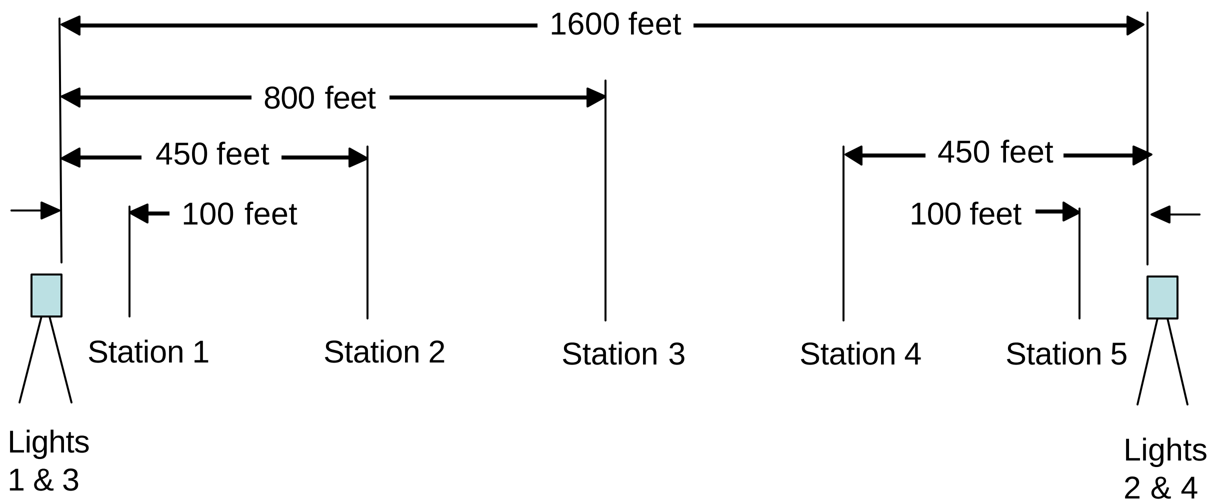

Figure 89. Field Test Layout.

Depending on which station the volunteers were at, each signal group operator set the signals to display the correct test pattern according to the test layout they were given. The following list shows some of the steps taken to administer the field test:

1. The volunteers are given an informed consent form to read and sign.
2. Each volunteer is given the simple eye exam.
3. Response forms were then handed out to the volunteers.
4. The volunteers were taken to station 1, located 100 feet from Signals 1 (NPS#4) and 3 (WPS#3) and 1500 feet from Signals 2 (WPS#2) and 4 (NPS#1).
5. Once the volunteers reached station 1 they were turned to face signals 2 and 4 while the signal 1/3 operator illuminated signal 1.
6. The volunteers were turned around and asked to look at Signal 1 and mark on the test form if the signal appeared to be on, off, or if it was not clearly perceivable.

7. While the volunteers were evaluating Signal 1, the operator of Signals 2 and 4 illuminated Signal 2.
8. After the volunteers evaluated Signal 1, they turned and faced Signals 2 and 4 where they evaluated if Signal 2 appeared to be on, off, or unclear.
9. While the evaluation of Signal 2 was underway, the Signal 1/3 operator turned off Signal 1 and illuminated Signal 3.
10. When ready the volunteers were instructed to turn and face Signals 1 and 3 again and evaluate Signal 3.
11. Similarly, the Signal 2/4 operator turned off Signal 2 and illuminated Signal 4. The volunteers then turned one last time and faced Signal 4 and evaluated it.
12. After evaluating all four signals, the volunteers were escorted to the next station.

The volunteers and signal operators repeated this procedure at each station between the signal pairs. The volunteers were routinely reminded not to compare signals but to evaluate how each signal appeared. Also, the failure patterns were varied at each station per the test layouts to discourage comparison. The distances for the 5 stations the volunteers were asked to observe the signals from is given in Figure 89.

After the volunteers had finished with the test, they were given new forms and repeated the procedure with one of the other pre-arranged LED pattern tests. Since the volunteers were already located at station 5 they were faced toward Signals 1 and 3, and the Signal 2/4 operator prepped Signal 2 for viewing. The volunteers then turned and evaluated Signal 2. The Signal 1/3 operator meanwhile set up and illuminated Signal 3. The previous test procedure was repeated with a few changes. The volunteers were moving through the stations backwards and because of this they viewed the signals in a different order: Signal 2, then 3, then 4 and finally Signal 1.

Throughout the field test the signal operators and the field-test conductor maintained a line of communication through the use of two-way radios. The radios were used so that the operators could inform the test conductor that signals were ready for viewing. Also the test conductor would inform the signal operators what signal the volunteers were observing and when the volunteers were in transit to the different stations.

Students and faculty members within the College of Engineering were recruited as volunteers. Volunteers were used because the nature of this test depends on how people perceive the LED signals. Every person is different and so perception is likewise particular to each individual. Seventeen volunteers participated in four separate field tests. Twelve of the seventeen volunteers were between the ages of 19 and 24. The remaining five volunteers were over thirty years in age. A wide age range was desired to include the effects of aging on vision. Also, the older volunteers are a better representation of a typical train crew. Of the volunteers tested, 8 were females and 9 were males. Figure 90 shows one of the volunteer groups that participated in the field test.

Figure 90. Volunteers during field test.

Palmore Park was chosen as the test site for a number of reasons. First, it met the distance constraints for the test – a total distance of 1600 feet with room to set up the test stands. Secondly, it could be reserved through the Tuscaloosa Parks and Recreation Association. Finally, it was a low traffic location with large flat open spaces that provided the fewest number of hazards for the volunteers and the least amount of distraction for road traffic.

Upon reaching the test site each volunteer was given a consent form to read and fill out. The purpose of informed consent is to protect the rights of the volunteers while providing them with information about the test. Before the field test, volunteers were given a simple vision test. The results of the vision tests were used to screen the experiment results. For instance, if someone's vision was 20/200 or worse then they would not be expected to see any of the signals. The volunteers were not prepped for the vision test, so their "normal vision" could be tested, since this is the vision they would be using while driving.

Failure patterns were chosen arbitrarily and by the LED signals' limitations. Some of the LEDs could not be completely controlled due to the way the signals were constructed. Signal WPS#2 had a structural member on the back of the integrated circuit that could not be removed and so the three middle rows of LED lights could not be turned off except by disconnecting the signal's power source. Signal WPS#3 had a built in feature in that it began to flash when a certain number of the LEDs were turned out. Each light had its LEDs grouped in sets. Thus, to simulate failures, LEDs were activated or deactivated in bundles created by the manufacturer. Failure patterns were chosen based on percentages of the LEDs. The patterns that were used were roughly 0%, 25%, 50%, 75% and 100%. This was done to simplify the tests for the volunteers and to minimize the number of electrical modifications needed for each light.

For each field test, two pre-planned sets of patterns were chosen for each signal depending on the observation station. The observation stations were arbitrarily chosen at varying distances between the sets of signal lights. The patterns to be shown at each station were decided upon by following a design matrix. By utilizing a design matrix, it was not necessary to test each pattern at each station. This made the test easier for volunteers to follow and took less time to complete.

The results from the volunteer response forms are summarized below. Volunteer responses marked as "off" or "unclear" were both counted as signal failures. In addition, volunteer responses marked "on" with comments such as "barely" or "maybe" were counted as signal failures. The results discussed below also include volunteer responses for signals that were completely off and fully illuminated. The test provides the opportunity for subjects to report misinterpretation of the signal without being influenced by what happened at greater distances. It also provides for subjects to report lights being "on" when no LEDs were illuminated.

Results for NPS#1

The NPS#1signal was recognized as “on” at all distances when 75% or 100% of the LEDs were illuminated and at distances near to the signal when 50% of the LEDs were illuminated. The signal was misinterpreted at each distance by at least one volunteer when 25% of the LEDs were illuminated. At 100 ft, almost 60% of volunteers misinterpreted the signal. In addition, the signal was unclear at close distances when only 50% of the LEDs were illuminated. A bar graph of volunteer responses is in Figure 91.

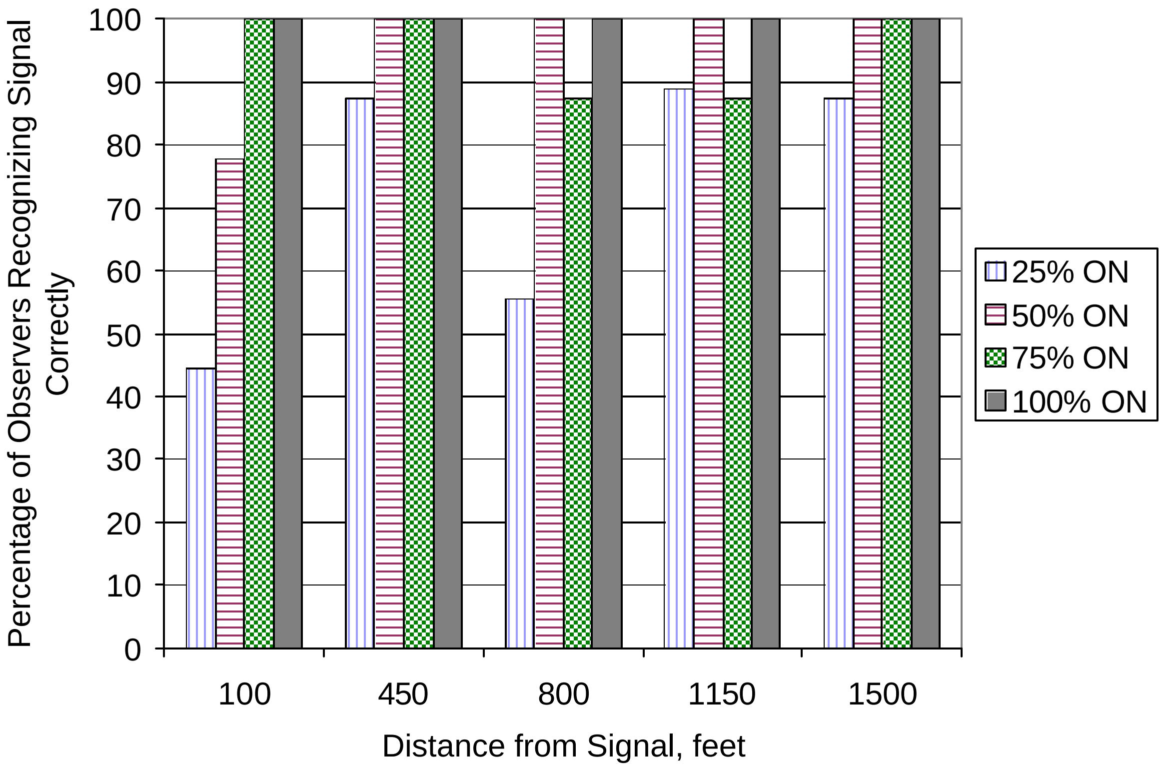

Figure 91. Volunteer responses for NPS#1.

<u>Results for WPS#2</u>

The WPS#2 signal was recognized as “on” at all distances when 75% or 100% of the LEDs were illuminated and at close distances when 50% of the LEDs were illuminated. The signal was misinterpreted at all distances when only 25% of the LEDs were illuminated and at greater distances when 50% of the lights were illuminated. A bar graph of volunteer responses is shown in Figure 92.

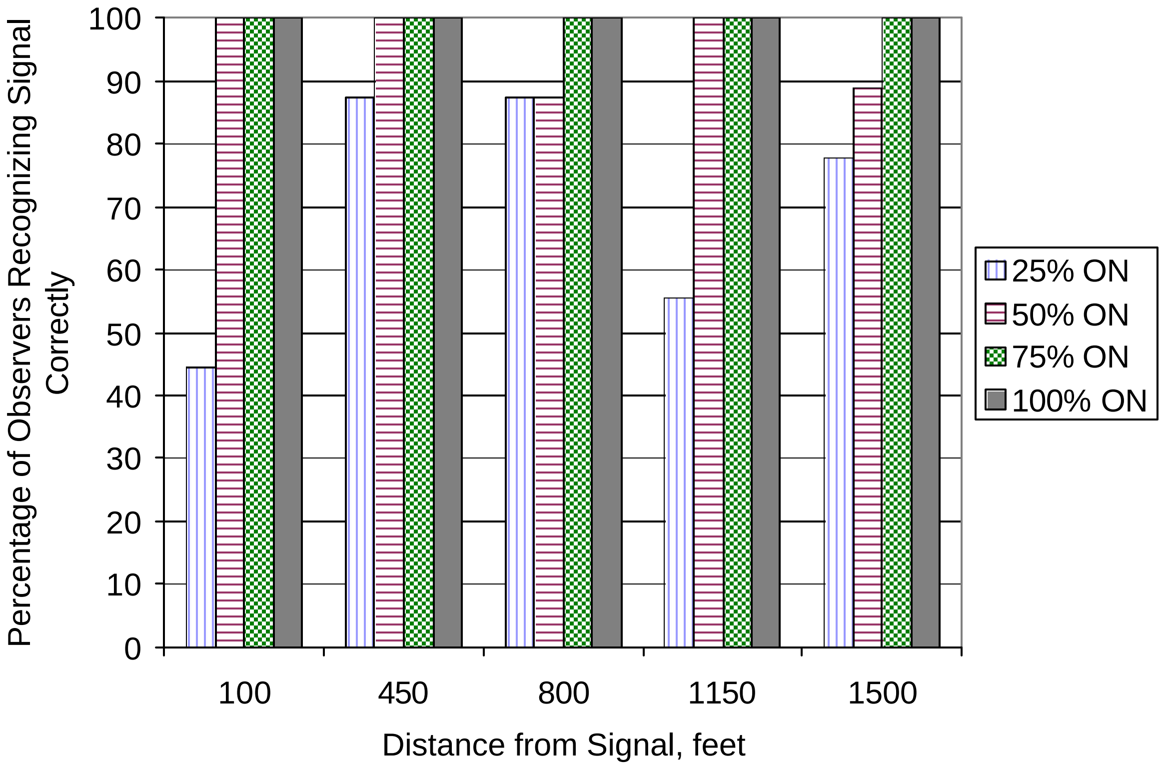

Figure 92. Volunteer responses for WPS#2.

Results for WPS#3

All volunteers recognized signal WPS#3, as "on" at all distances when any portion of LEDs was illuminated with only two exceptions. The signal appeared unclear at 100 ft when 25% of the LEDs were illuminated. As discussed previously, this is due to the ability to distinguish between non-illuminated and illuminated portions of the signal at close distances. Also, the signal appeared unclear to one volunteer at 1500 ft when 75% of the LEDs were illuminated. A bar graph of volunteer responses is in Figure 93.

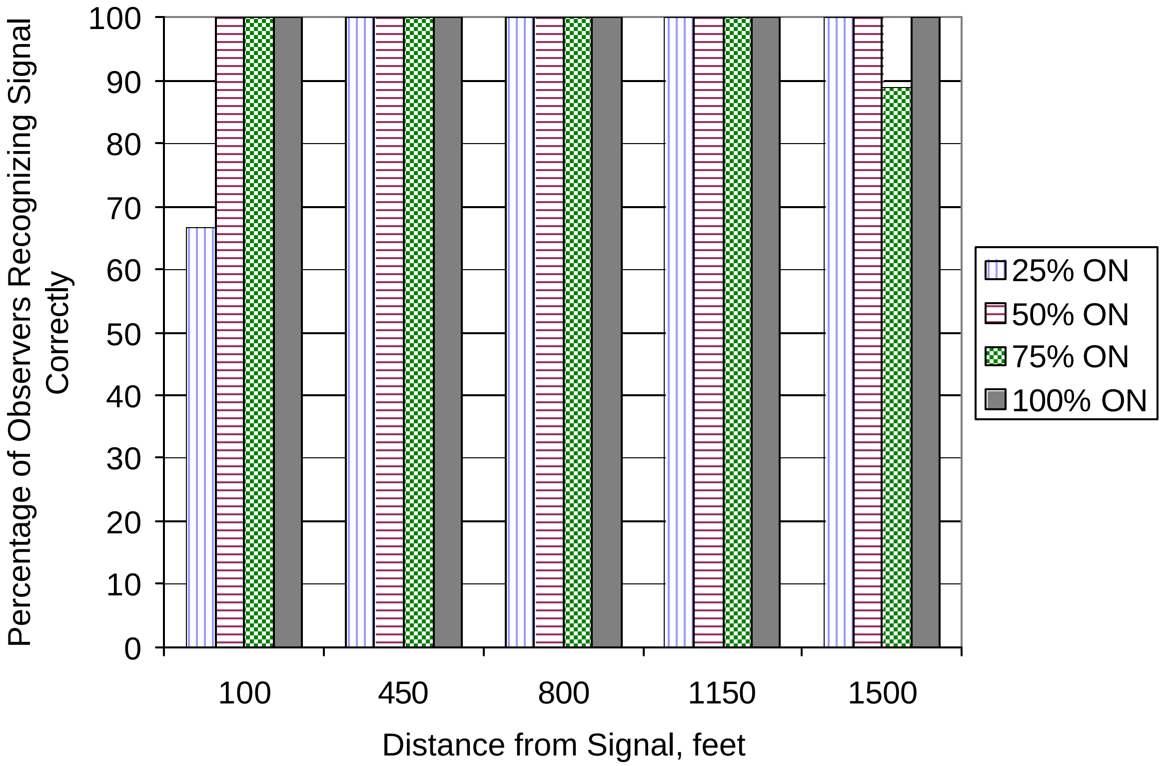

Figure 93. Volunteer responses for WPS#3.

Results for NPS#4

The NPS#4 signal was recognized as "on" by all volunteers at all but one distance when any portion of LEDs was illuminated. The only exception is one volunteer who responded that the signal was unclear at 100 ft when 25 % of the lights were illuminated. This signal might appear unclear to an observer at close distances because it is possible to distinguish between the illuminated and non-illuminated LEDs. At distances farther from the signal, an observer cannot distinguish individual LED sections. The volunteer responses are shown in Figure 94. In addition, one volunteer incorrectly responded that the signal appeared to be ON at a distance 1500 ft away from the signal. This test was conducted on a sunny day and glare from the sun may have caused the signal to appear on when no LEDs were illuminated.

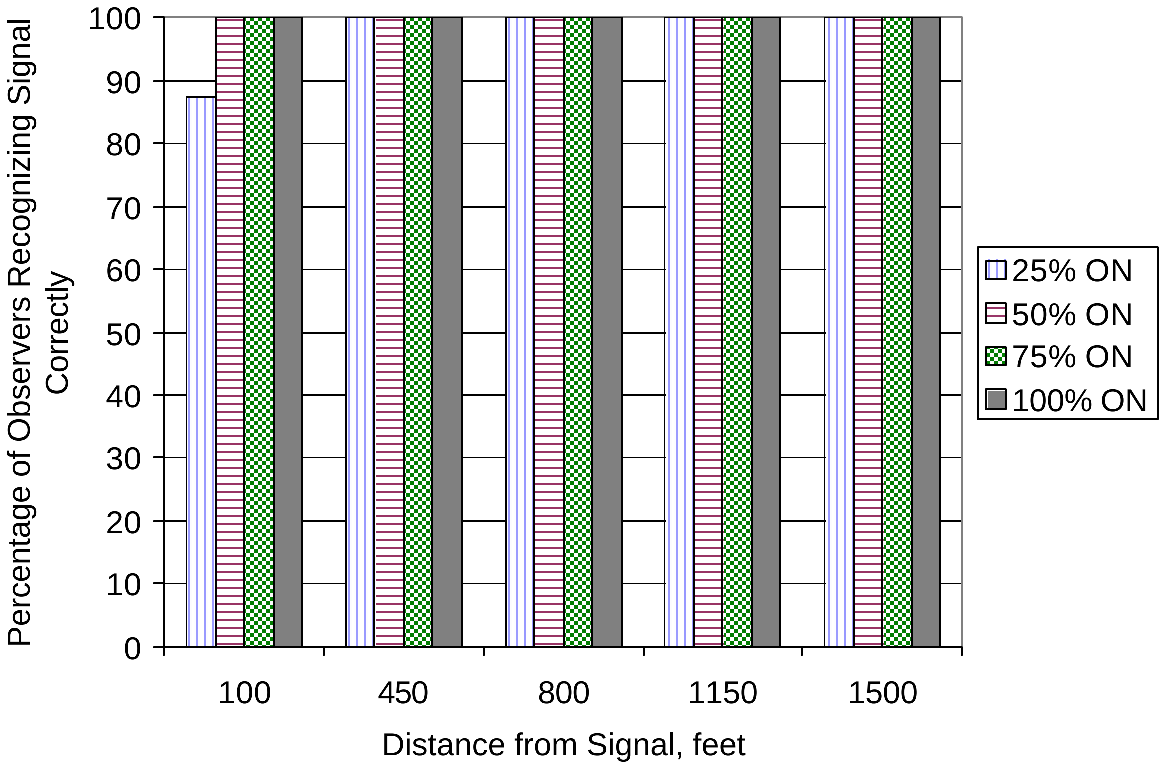

Figure 94. Volunteer responses for NPS#4.

No field tests were conducted with the other five LED signals – WPS#5 through WPS #9. As shown in the lab results, there are relatively small differences in the light intensity output for these six signals as a function of the percentage of LEDs that are on. Results from the initial four 12 inch red crossing signals indicated that it is difficult to quantify relatively small differences in light intensity with field tests. This is believed to be partially due to the logarithmic response of the human eye. Another factor is the field test procedure itself, where test subjects know the location of the LED signal and are able to see it in almost all conditions. The highly focused beams used in the 8 inch crossing signals would almost certainly always be seen while on-axis regardless of the percentage of non-illuminated LEDs. The off-axis response would also not be a function of the percentage of non-illuminated LEDs.