AVALANCHE RESCUE: FREQUENCY VARIATION AS A SEARCH METHODOLOGY

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ABSTRACT

A comparison was made of the human ear's sensitivity to detecting variations in frequency versus variations in amplitude. The purpose was to investigate a potential improvement in the effectiveness of avalanche victim search and rescue operations. Twenty subjects performed simulated searches using a computer mouse located on a grid, which enabled the tracking of search paths. Subjects performed course searches and used bracketing to pinpoint victims. Various electronic instruments were used to simulate both frequency and amplitude variations. The subjects performed 18 individual searches. Path lengths were analyzed by recording mouse movement over the search grid. Individual search times were normalized and an overall comparison of detection, convergence, and the total search times for both frequency and amplitude variations were made. The effective sizes of the search or detection circles of both methods were determined in order to analyze their effect on search times. For each site a comparison was made of the effectiveness of each method by plotting frequency detection time versus amplitude detection time. It is suggested that the frequency variation method can provide shorter victim detection time.

INTRODUCTION

Lind and Smythe first discussed the possibility of using frequency as an avalanche transceiver detection method at the 1984 ISSW conference in Aspen, CO. This idea is based on the human ear's ability to hear a change in frequency (tones) better than a change in amplitude (volume). Through conversations with Dr. Milton L. Olsson[2], this concept was further verified. A frequency range of 1000 Hz to 1300 Hz was selected. This range was selected as a representative variation which would fall well within the ear's hearing range.

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BACKGROUND

Currently, all known avalanche transceivers use audio signal amplitude variations as their means of signal detection which guides a rescuer closer to an avalanche victim. Once the signal is found, bracketing, as described by the U.S. Forest Service Avalanche Handbook, is used as shown in Figure 1. The rescuer marks the beginning and end points of audible signal detection, proceeds to the midpoint between these and repeats this method to pinpoint the victims position.

The critical process during bracketing occurs at the turning phase of the procedure. Here, efficient time utilization and accuracy of the turning location play a critical role. In order to minimize search time, many professionally trained rescuers use a bracketing search pattern similar to Figure 2. In this procedure, the rescuer makes a turn as soon as a discernible difference in the signal is detected. This method may prove to be faster, but the rescuer may also err and lose valuable time backtracking.

In order to best facilitate the bracketing procedure, most avalanche transceivers are equipped with a sensitivity adjustment which produces smaller search circles by reducing the receiver sensitivity. This effectively increases the resolution of the avalanche transceiver when the rescuer moves progressively closer to the victim.

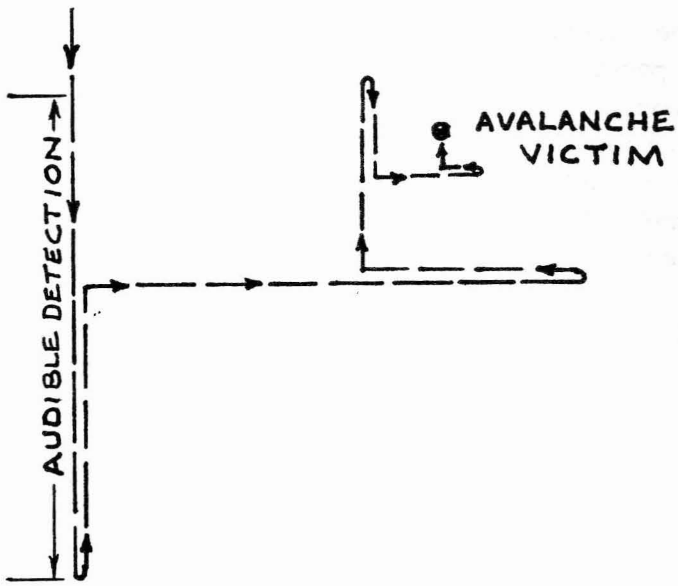

Figure 1. U.S. Forest Service Avalanche Handbook recommended bracketing method.

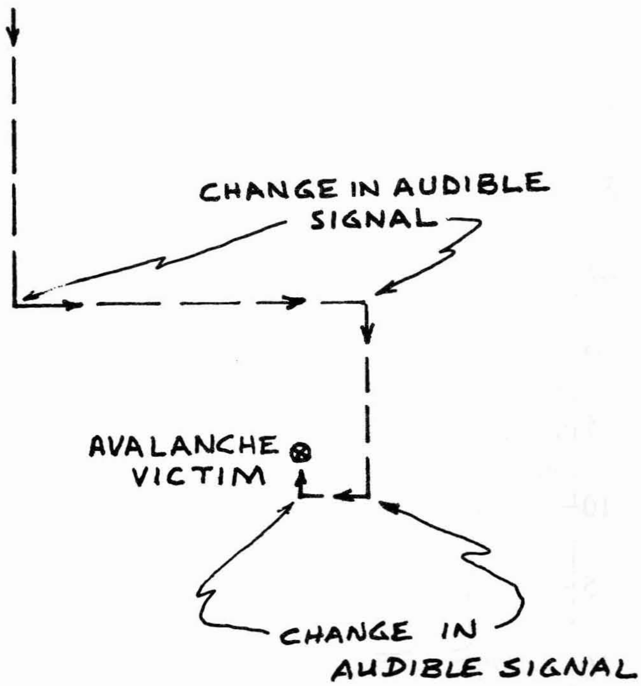

Figure 2. Professional rescuer adaptation of U.S. Forest Service bracketing method.

APPARATUS

The purpose of the project was to compare the human ear's response to frequency variations with its response to amplitude variations in a similar avalanche victim search environment. Thus, in order to eliminate as many external factors as possible, the comparisons were made indoors using computer simulation of the search process. This dispensed with the high cost and impracticality of a field experiment using actual avalanche transceivers. A three-foot square grid was laid out on a table as a simulated avalanche rescue site. Eight victim locations were established with positions unknown to the rescuers. A computer and mouse were used to determine path length.

The apparatus was developed principally from common laboratory equipment. A continuous 1000 Hz sinusoidal signal was used to excite a small coil placed beneath the grid at a selected victim location. The magnetic field produced by the coil thus simulated the effects of a victim's avalanche transceiver. The computer mouse, which was guided by the searcher, carried a small coil suitable for detecting the magnetic field of the victim's transceiver. When the detection coil was located in the vicinity of the simulated "victim," a small voltage was induced in the coil. This 1000 Hz voltage was filtered and amplified by a narrow band wave analyzer.

When an "amplitude" search was simulated, the voltage out of the wave analyzer was further amplified and presented to the searcher as a monophonic signal via stereo headphones. In this case, the closer the mouse coil moved toward the "victim" the louder the tone heard by the searcher. There is a

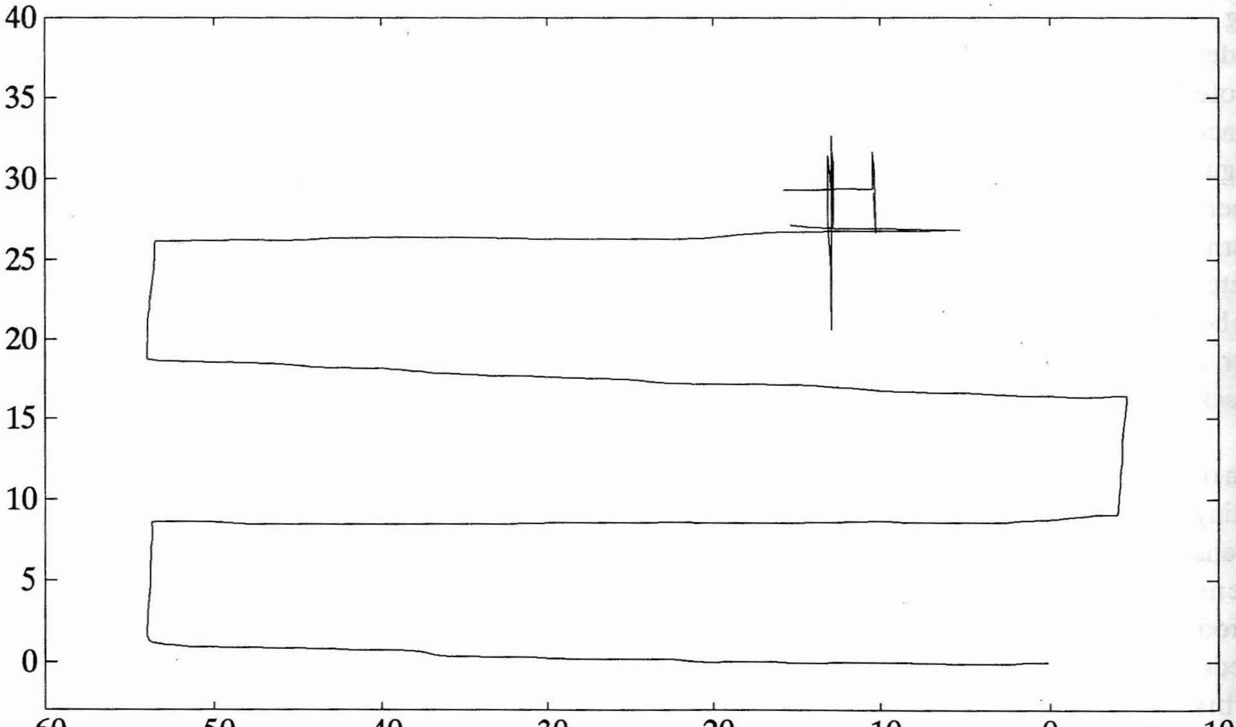

Figure 3. Typical search path by subject (scale in tenths of meters).

maximum distance for detecting a tone which is audible to the searcher: when the distance from the mouse to the victim is greater than this maximum, no tone is audible.

When a "frequency" search was simulated, the small constant frequency signal out of the wave analyzer was converted to a dc voltage proportional to the amplitude of the constant frequency signal. This voltage was then used to control a voltage-to-frequency converter where the voltage-frequency relation was designed to be nonlinear. The result was a sinusoidal signal with a frequency that varied nonlinearly with variations in the amplitude of the 1000 Hz signal out of the wave analyzer. After amplification, the signal was presented to the searcher as a monophonic signal via head stereo phones. Thus, closer proximity of the mouse to the victim resulted in a constant amplitude tone which increased in frequency.

It is important to note that both methods, amplitude and frequency, were driven by exactly the same signal out of the wave analyzer. In effect, these two methods used the same physical principal for detection, but presented the detected signal to the searcher differently.

Each "rescuer" used both methods to search for randomly placed victims. Earphones were used to minimize distractions. For each search, the operator used a stopwatch and recorded three times: detection (time from start of search until initial detection of victim), convergence (time from detection until victim was located by rescuer), and total (sum of detection and convergence times). The computer tracked the path and plotted the searcher's course. All "rescuers" were volunteers with minimal experience in avalanche search and rescue techniques. Each received a sheet of directions which specified the use of rectangular movements while using the mouse and diagramed the bracketing technique to be used in the final search. A typical rescuer search path is shown in Figure 3. No sense of urgency was introduced into the task. Each subject was allowed to search at their own deliberate rate of speed.

RESULTS

Path Lengths

Individual search path lengths were statistically analyzed comparing both frequency and amplitude path lengths at the various individual site locations. There were no significant differences between the path lengths for either method. The individual plots of each rescue operation were printed and analyzed. Upon analysis, an error was found in the apparatus. The mouse used worked on a roller-ball principle and did not always track properly during searches unless maintained in a rigid x-y coordinate orientation. This significantly affected plotted path shapes and eliminated their utility in determining, via computer, the accuracy of each subject's victim pinpointing. Use of an optical mouse would solve this problem.

Detection Time

Detection, convergence, and total search times were compared for the two search methods. A comparison of detection search times for a single site, designated "purple," is shown in Figure 4.

Frequency detection time is plotted against amplitude detection time for each victim burial site. Rescuers taking equal times for a particular site would be shown somewhere on a 45° line extending from the origin and labeled as equivalent time. Seventeen of the 20 subject results are shown in the figure. Rescuers whose detection times were longer using frequency variation than amplitude variation are plotted above the 45° equivalent time line. Rescuers whose detection time was longer using amplitude variation are plotted below the 45° equivalent time line. The mean for all detection times is also shown. The mean of 38.1° shows that on average, the frequency search method required only 78% of the time of the amplitude search method. Examination of Figure 4 shows that six of the subject's detection times were smaller for amplitude searches, while nine detection times were smaller for frequency searches and two subjects displaying equal times for the two methods.

Figure 5 shows all of the data taken for the eight victim positions. The total number of data points are: (8 victims) x (2 search methods) x (20 subjects) = 320. When plotted as frequency versus amplitude, this results in 160 data points. The same conclusions drawn for Figure 5 are valid for the entire data set. A feature common to both Figure 4 and Figure 5 is the wide variation in search times from one subject to another for the same task. For example, in Figure 4, a higher than 4:1 ratio is shown (18 seconds for the fastest amplitude search, versus 80 seconds for the longest amplitude search). No effective normalization scheme was found, and a simple plot of one method's time versus another method's time was chosen to provide the necessary comparison.

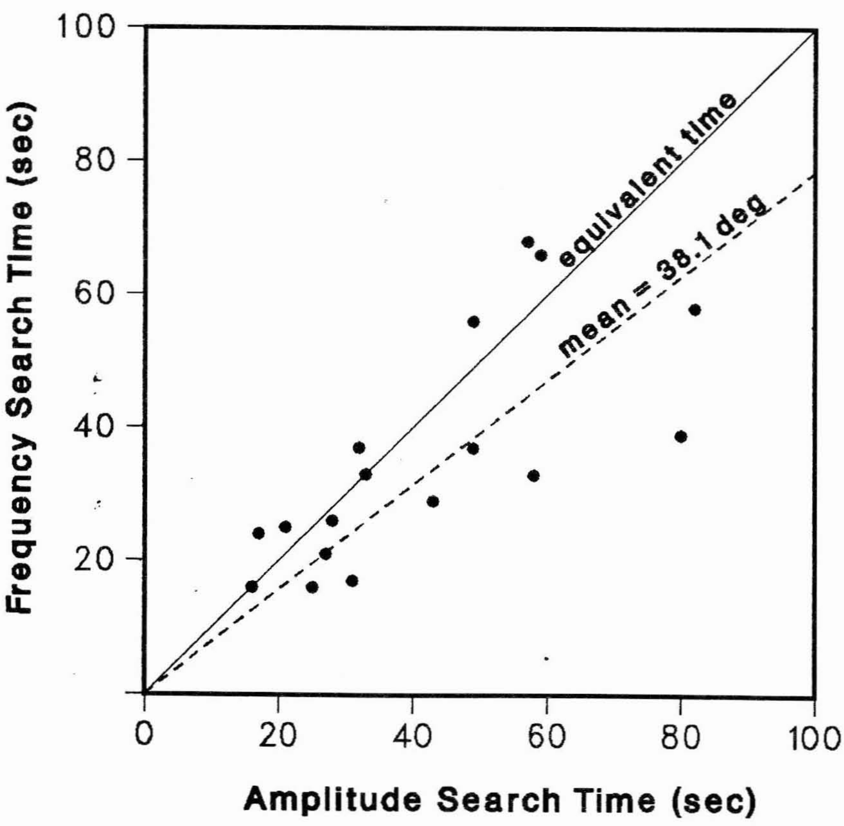

Figure 4. Detection times for the purple site.

It is observed in the figure that more often than not the frequency variation method produced faster detection times than the amplitude variation method. The reason for this behavior is explained by the different detection circle sizes for the two methods. In a separate experiment a victim was placed randomly along a line and the rescuer was instructed to move along the line and note when the victim was first detected. In this manner the detection circle for frequency detect was shown to be 25% larger in diameter than for amplitude detect even though, as noted earlier, the same basic signal was used during each method of comparison. Since data from all eight search tasks are

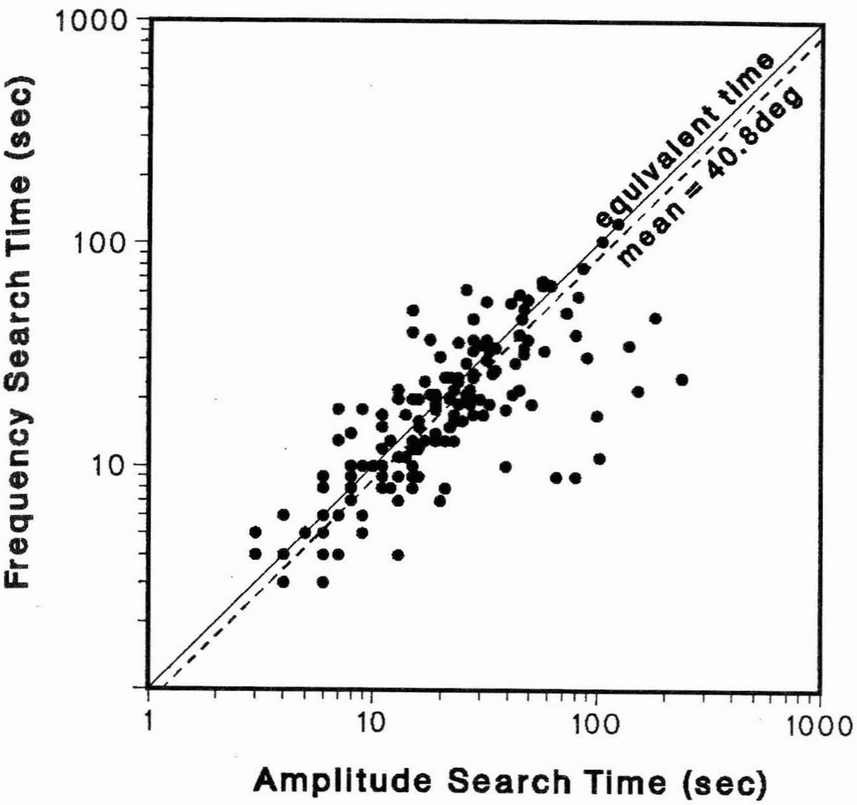

Figure 5. Detection times for all sites.

included in Figure 5, a wide variation in time is observed. The log-log plot allows all data to be presented on one figure, with the average detection time ratio indicated as a line parallel to the 45° equivalent time line. In this case the mean of 40.8° shows the frequency search method required only 86% of the time of the amplitude search method.

Convergence Time

Convergence time was also analyzed and amplitude detect proved to be faster than frequency detect. This may be due to the fact that the initial starting distance from the victim for the frequency detect was 25% larger than for amplitude detect because of the larger search circle.

SUMMARY

In summary we can suggest that our project showed that the frequency detect method is superior to the amplitude detect method. The principal reason for this conclusion is that the detect circle was larger for the frequency detect than for the amplitude detect even though they used exactly the same detection coil and preconditioning filter. We suggest that the greater sensitivity of the ear to frequency variations than to amplitude variations is the reason for this superior performance.

Also, given the bracketing technique shown in Figure 2, it is believed that the frequency variation method can provide faster convergence times than the amplitude variation method for equal detection circle diameters.

Further, individual subjects preferred using frequency variation to detect a victim and amplitude variation to converge to the victim's position. The reasons for this pair of choices is not fully understood. However, we suggest that an investigation of gain variation (alteration of detection circle size) could resolve this point. For the above reasons, continued investigations into this concept are thought to be quite desirable. Additional improvements in the experiment design coupled with increased statistical data should serve to further resolve the relative effectiveness of the two methods.

ACKNOWLEDGEMENTS

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