MULTIPLE BURIAL BEACON SEARCHES WITH MARKING FUNCTIONS – ANALYSIS OF SIGNAL OVERLAP

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ABSTRACT: Locating multiple buried avalanche victims can be a difficult job for the average recreationalist. To simplify the task, modern avalanche beacons have added "marking" functions that allow a signal to be digitally removed from the search once it is pinpointed. The marking functions identify individual transmitters based on small differences in their pulse periods and/or frequencies. These systems work well when the individual pulses remain distinct, but they can become unreliable when two or more units move "into phase" and send transmit pulses at the same time over many cycles. Although this so-called "signal overlap" problem is well known, its rate of occurrence has not been quantified. Through a combination of electronic analysis and computer simulations, we have determined the likelihood of extended periods of signal overlap for various combinations of transmitters. The results show that long periods of signal overlap can occur when searching for certain older models: There is a 60% chance that four of these beacons will remain overlapped for at least one minute. Since the marking features may be difficult to use during these prolonged periods of overlap, we recommend that educators continue to teach standard multiple-burial search techniques and make sure users know how to disengage the marking functions when necessary.

KEYWORDS: Avalanche beacon, Transceiver, Marking, Multiple burial, Signal overlap

1. INTRODUCTION

In the past decade, great advancements have been made in the field of avalanche transceiver rescue, most notably the worldwide acceptance of digital technology. Since 1997, average rescue times have decreased dramatically, increasing the odds of survival for avalanche victims. But as avalanche beacon technology becomes increasingly sophisticated, it can become less compatible with the existing mass of beacons already in use. This is particularly the case with new digital transceivers that use signal timing analysis to “mark” victims in complex multiple burials. While this system works well under ideal conditions, it can be unreliable when more than one transmitter send pulses simultaneously, a situation known as “signal overlap”.

Using a combination of computer modeling and field trials, we determine that “signal overlap” can be a real concern when using “marking” functions to search for as few as two beacons at a time. The problem is further compounded as the number of signals increases. For this reason, “marking” functions should not be expected to completely replace existing methods for isolating multiple burials. Although “marking” may be valuable in solving complex multiple burials, users must also be ready to execute reliable backup techniques such as the Three Circle (Stopper and Semmel, 2004) and Micro Search Strip methods (Genswein and Harvey, 2002, Blagbrough and De Montigny, 2006) in case signal overlap confuses the marking features.

2. DEFINITIONS

To study the issue of signal overlap, it is first important to define several concepts inherent to transceivers, which are shown in Figure1.

Signal amplitude: The strength of a signal, measured in volts. In oscilloscope images, this is the height of the signal.

Pulse width: The “on-time” of the transmit pulse.

Pulse period: The overall time period between the leading edge of one pulse in a beacon’s “pulse train” and the leading edge of the next pulse.

3. SIGNAL STRENGTH ANALYSIS

Traditionally, signals in multiple burials have been isolated using the process of signal strength analysis, either manually (when using analog beacons) or automatically (using most digital beacons). When performed manually, the searcher uses his or her sensitivity control to identify the closest transmitter, then locates that signal using a bracketing or induction line search technique. With

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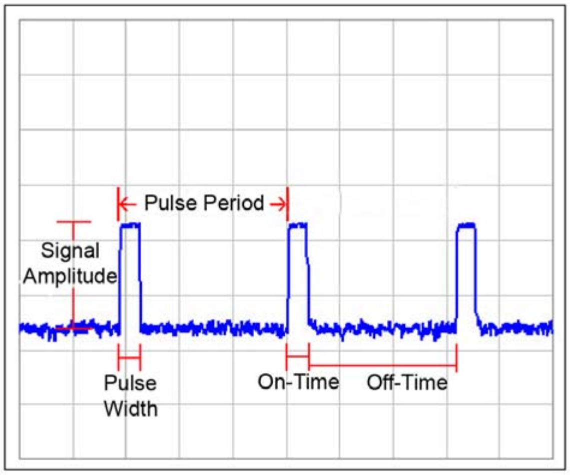

Figure 1. This transmit signal has a relatively narrow pulse width, or “on-time” relative to the overall pulse period. High amplitude makes it easy to distinguish from background noise and other transmitters.

most digital beacons, this is performed without the use of a sensitivity control: the microprocessor analyzes the relative amplitude of each signal and leads the searcher to the strongest signal first by only displaying the distance and direction of that signal.

Once the first transmitter is pinpointed, the subsequent victims are located by repeating this procedure after moving away a sufficient distance to cause the receiver to lock onto a different transmitter. The Three Circle Method, Micro Search Strip Method, or Special Mode (which deactivates signal strength filtering and narrows the receiver’s field of view) can be used to ensure that all victims are found quickly, even if they are buried in close proximity.

4. SIGNAL TIMING ANALYSIS

In recent years, some digital beacon manufacturers have developed signal timing analysis to supplement or replace standard signal strength analysis for multiple burial searches. In this case, the microprocessor analyzes a series of transmit pulses and establishes patterns that enable it to identify each transceiver by the timing of their pulse period (the time measured between the leading edge of one pulse and the leading edge of the next pulse).

The benefit of signal timing analysis is that once a transmitter is clearly identified by its pulse rate, it can be “marked,” or canceled after it is found. Then the searcher can move on to the next signal without performing any special search procedure. While this sounds quite simple and can work well under ideal conditions, it can break down when the victims’ transmit pulses happen to be on at the same time (overlapped).

When pulses are overlapped, it can be difficult for the receiver to distinguish between them. If the signals are overlapped while the searcher is attempting to “mark” one of them, it is possible for the wrong transmitter to be taken out of the search. This situation results in the inability to locate this incorrectly “marked” beacon. Also, the number of victims shown on the display is often inaccurate. These issues can make a multiple-beacon search unreliable and more complicated than a traditional search using signal strength analysis.

5. SIGNAL OVERLAP: SCOPE OF THE PROBLEM

How likely is signal overlap? In the field it can be very unpredictable. It is only a matter of chance (or bad luck) that the searcher will attempt to “mark” a victim when their signal is overlapping with another transmitter. In some scenarios it is quite rare and in others it can consistently scuttle a search. This is because the probability of signal overlap varies widely, depending on the number of transmitters and on their characteristics (pulse period and pulse width).

To determine the scope of the problem, we developed a computer simulation program to predict the overlap characteristics for various combinations of transmitters. Using measured beacon properties (pulse period and pulse width) for a wide selection of beacons, the computer program could accurately simulate the simultaneous operation of two to six beacons. Since the overlap characteristics change with time–and may be dependent on the relative timing when the units were turned on–it is necessary to consider a very large number of transmit pulses. The computer simulation steps through all of these pulses, keeping track of the durations of both overlapped and clear signal segments. As a consistency check, the computer simulation was validated through direct measurements of actual beacons monitored on an oscilloscope.

6. RESULTS

6.1 Mixed brands

In the first set of trials, overlap statistics were compiled for the 24 assorted beacons discussed by Eck et al. (2006). We considered all possible groupings of 2, 3, and 4 beacons and recorded the duration of all overlapped and clear pulse

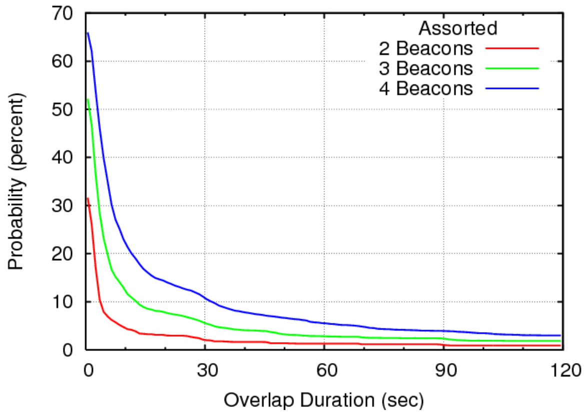

Figure 2. Probability of obtaining an overlap of specified duration for all possible combinations of two, three, and four beacons taken from the study of Eck et al. (2006).

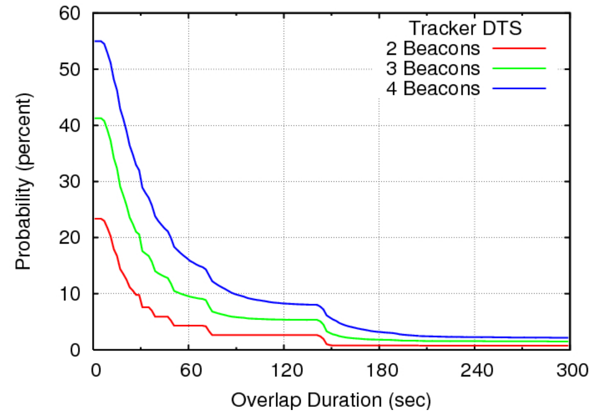

Figure 3. Probability of obtaining an overlap of specified duation for all possible combinations of two, three, and four Tracker DTS beacons.

segments for each. As shown in Figure 2, the results are displayed in terms of the probability of encountering an overlap lasting greater than or equal to the time shown on the horizontal scale. Figure 2 shows that, for three-beacon combinations of assorted brands, there is a 12 percent chance of encountering an overlap of at least 10 seconds, a 3 percent chance of an overlap greater than one minute, and a 2 percent chance of an overlap of at least 2 minutes. Figure 2 also shows that the likelihood of long overlaps increases with increasing number of transmitters. The probability of encountering a maximum overlap of at least one minute rises from 3 percent for two beacons to 6 percent for four beacons. It is also important to note that there is still a 1 percent chance of overlaps lasting more than two minutes for only two beacons. Our field tests with real beacons confirmed that overlaps lasting at least five minutes are possible with even two beacons.

6.2 Identical brands

The data displayed in Figure 2 is for a collection of assorted beacons that have widely varying pulse periods and pulse widths. As we shall show below, this is the most favorable situation and leads to the lowest probability of long overlaps. But what about regional preferences and guided operations that often result in an entire party using the same brand of beacon? To answer this question we chose collections of 24 Tracker DTS beacons and 24 Ortovox F1 beacons. These two beacons were selected since they are the two most common varieties found in the field worldwide. They are also interesting to study since they have rather different characteristics. The

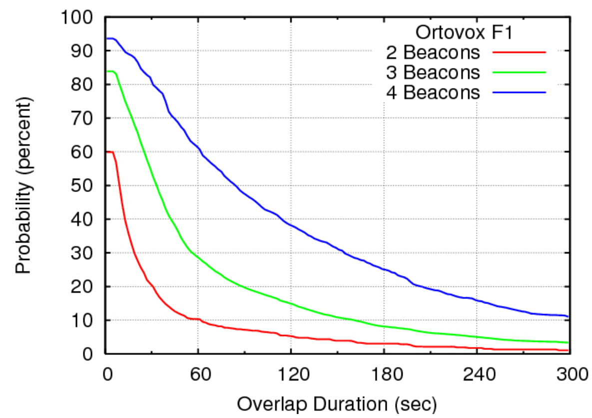

Figure 4. Probability of obtaining an overlap of specified duation for all possible combinations of two, three, and four Ortovox F1 beacons.

Tracker DTS is characterized by a fairly narrow pulse width and rather precise pulse period. The Ortovox F1, on the other hand, is characterized by a very long pulse width, and a wide range in pulse periods.

Probability of overlap for collections of two, three, and four Tracker DTS beacons and similar combinations of Ortovox F1 beacons are shown in Figures 3 and 4, respectively. These distributions are of particular interest since they both show a significantly greater likelihood of long overlaps. The probability of encountering an overlap lasting one minute or more is 16% in the case of four Tracker beacons and 60% in the case of four Ortovox F1's! Both beacon types are predicted to have a measurable probability of overlaps lasting at least five minutes with only two beacons. This probability rises to more than 10% in the case of four F1 beacons.

The reason for the relatively high probability of overlap in the case of the Tracker DTS beacons is the limited differences in pulse periods among various units. This feature results in small differences in the relative timing of pulses sent by different units from cycle to cycle and thus requires many pulses to move the signals out of overlap. This situation has prompted a few manufacturers (including BCA's Tracker2) to distribute significantly different pulse periods across units in such a way that it is unlikely to obtain two or more transmitters with very similar pulse periods. Randomizing the pulse periods in this way produces a situation similar to assorted beacons shown in Figure 2, with greatly reduced probability of overlap.

The mechanism for long overlaps in the case of the Ortovox F1 beacons is similar to that in the case of the Tracker, with the added complication that these beacons have very long pulse widths. When three beacons with similar pulse periods are grouped together, maximum overlap durations exceeding one hour are predicted! Since overlaps lasting at least one minute are predicted to occur more than 60 percent of the time in a four-victim burial, one would want to exercise extreme caution when using "marking" features to search for multiple victims wearing similar beacons with wide pulse widths.

7. RESOLUTION OF OVERLAPPED PULSES

Recently both Meier (2008) and Genswein (2008) have pointed out that a well-designed digital receiver can resolve two overlapped pulses, provided the edges of the embedded pulse can be identified. As Meier explains, whether or not this is possible depends on the relative amplitude of the two signals, the relative phase of the two transmitters, and the relative difference in their carrier frequencies. Unfortunately it is extremely difficult to account for variations in all these additional parameters in a computer simulation program such as the one used here. The exact details of the edge detection algorithms are also proprietary, making it impossible to reproduce them exactly. Due to these limitations, we are unable to identify the subset of overlapped pulses that might be resolved by a good receiver. Thus, although our results accurately show the likelihood of long periods of overlap, one should not immediately conclude that a good receiver would be useless during this entire period. What our results do show is that the edge detection algorithm needs to work hard during these extended periods of overlap and will certainly fail for a certain fraction of these pulses. It is a very difficult matter to say with certainty what fraction of overlaps might be resolved since this is so strongly dependent on the various parameters discussed above. Thus the present results may be regarded as the absolute worst case where none of the overlapped pulses can be resolved. In reality, one would expect better performance in most cases.

It should be noted that although good signal edge detection and classification algorithms can mitigate the effects of signal overlap, they can not completely eliminate it. Figure 4 shows that long periods of overlap are quite likely for certain beacons. Thus, even if Meier's (2008) estimate that roughly 80% of the overlaps can be resolved, this still leaves 12% of the pulses unresolved for a case where overlaps occur 60% of the time. This is a great enough probability to warrant the concerns raised in this paper.

8. CONCLUSIONS

Due to the potential unreliability of signal timing analysis, "marking" functions should be used primarily as a technique to possibly enhance a multiple burial search under ideal conditions. This is mainly limited to cases in which the transmitters are known to have pulse rates with a low probability of signal overlap—specifically transceiver fleets of mixed brands or of the same brands in which the pulse rates have been intentionally "randomized" to minimize overlap.

Before using any "marking" function, all beacon users should be fully proficient in the use of standard signal strength-based search procedures. If this is not taught, then relying on "marking" functions alone could decrease the probability for live recovery in certain situations. This is why, in their manuals, the manufacturers all suggest using a "backup" technique if more than three victims are buried.

The most widely accepted techniques for complex multiple burial searching—other than simply turning off the found transmitters—are the Three Circle and Micro Search Strip methods. The Three Circle Method was developed by the German Alpine Club (Stopper and Semmel, 2004) and is particularly suited to large deposition areas. While the Micro Search Strip Method (Genswein and Harvey, 2002) can be quite complicated, a simplified version (Blagbrough and De Montigny, 2006) has been widely adopted in Canada, as it is particularly well-suited for guiding exams in which the deposition area is limited.

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