Avalanche Transceivers & Multiple Burials

Story by Felix Meier

Avalanche beacons and multiple burials are a controversial issue. By evaluating properly selected signal features and by using suitable classification algorithms, it is possible to resolve multiple burial situations correctly in most of the cases, thus providing good guidance especially to users that never or rarely practice multiple burial searches. Some modifications to the standard EN 300 718, however, would make the process even more reliable.

INTRODUCTION

The issue of avalanche beacons and multiple burials has been discussed in two recent contributions [1], [2] in *The Avalanche Review*. The first one [1] seems to be rather optimistic, but since we do not have pertinent data at hand, it will not be discussed here. The second one, [2], is rather pessimistic, and there are quite some arguments why the issue is much less of a problem than suggested in that paper.

PROBLEM STATEMENT

A certain percentage of avalanche accidents involve multiple burials [1], [3]. As explained in [1], part of these cases can be resolved using single burial search tactics. But some cases require a more sophisticated approach because there is a high probability that the searching transceiver will receive signals from multiple transceivers simultaneously.

Two search strategies are available for resolving such situations: The Micro Search Strip Method [3] and the Three Circle Method [4]. Both strategies require some practice for efficient use. But it is a sad fact that about 90 percent of the transceiver users practice less than one hour per season, so in most cases they will not be able to apply any of these strategies properly.

Any support for resolving a multiple burial situation that can be made part of the transceiver functionality will therefore be very helpful to most of the users. Even if such support is not perfect, it is still better than no support at all.

MULTIPLE BURIAL ALGORITHMS

A good algorithm for resolving multiple burials is based on the following method:

At the end of the receiver chain, a suitable method is used for extracting one (or more) features of the received signal that shall be used for classifying it. The classification system then enters every new signal feature record into a pool of unassigned records. Every time a new record is added to this pool, the pool is checked for a subset of records that exhibit identical features and can therefore be assigned to a single transmitter. Once such a subset has been found, all records pertaining to it are removed from the pool and are assigned to a chain of records pertaining to a particular transmitter. When a new record comes in from the feature extractor, it is first checked for matching an existing chain of records. If it does match a pre-existing record set, it is assigned to that chain, and it may also be used for adjusting the feature values. If it does not fit into an existing chain, it goes to the unassigned records pool, and the pool is analyzed again for a possible new chain of signals from a new transmitter.

If a record fits an existing chain, it can be used for displaying information about the transmitter to the user if the user has selected that chain for display. If the user has "marked" that transmitter, the internal data records will be updated, but there will not be any indication to the user. This is to prevent signals from that marked transmitter from disturbing the search for another transmitter.

SIGNAL FEATURES

There are several features that may be used for characterizing the signal from a transmitter:

Pulse amplitude (or signal strength, for that purpose), is a measure for the distance to the transmitter. Since the strength of the received signal is also dependent on the relative orientation of the transmitting and the receiving beacons, it is subject to a lot of variance. Just imagine a searcher walking on avalanche debris and keeping his transceiver in the same orientation – nearly impossible. So it is really not a good idea to use pulse amplitude for classification.

Another feature that has been proposed for classification is the exact frequency of the transmitter [2]. Algorithms for extracting frequency information from a time domain signal are well known and widely available, e.g. the Fast Fourier Transform (FFT). One of the fundamental laws of those algorithms states that the obtainable resolution in frequency is equal to the reciprocal of the time duration of the signal sample being analyzed. The shortest transmitter pulse duration allowed by the standard EN 300 718 [5] is 70 ms. In order to not create any artifacts in the frequency domain, the signal to be analyzed should cover the entire interval under investigation. If no overlap is used (and that is pretty much a necessity because anything else would require enormous computing power), the maximum duration of the signal sample is thus 35 ms, resulting in a frequency resolution of at best 28.5 Hz. But most transceivers transmit within about ± 20 Hz of the nominal carrier frequency of 457'000 Hz, so that feature would not be very helpful for classification since most of the time, the signals from multiple transmitters would show up in the same frequency bin. The FFT algorithm is very computation intensive, and so there is very little bang for the buck when using this feature.

A third feature that can be used is the position of the signal pulse edges on the time axis. This feature is independent of the relative orientation of the transmitting and of the receiving antennas, and it can be measured with high resolution by a signal processor. Also, its short term stability is excellent unless the signals are emanating from an "intelligent transmitter". For more on that, see farther down. As has been explained in [2], when pulses from multiple transmitters overlap in time, some problems come up. But contrary to [2] which states that overlap makes multiple transmitter detection impossible and may lead to false "masking", we do believe (and we have checked it by practical implementation) that by proper evaluation of the received signal it is still possible to correctly handle multiple transmitters as well as "marking" most of the time.

When signals from multiple transmitters overlap, there will be steps in the amplitude:

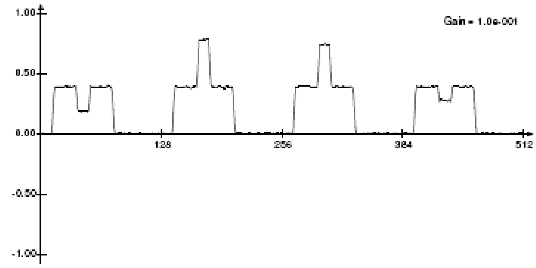

Fig. 1 Overlap

This is a simulated overlap of pulses from two transmitters at equal distance. The pulse duration is 300 ms, the pulse interval is 1000 ms for both transmitters, the second one of them is offset by 100 ms in time relative to the first one, and they transmit at exactly the same frequency. So the pulses do overlap for a duration of 200 ms. It may be surprising that the signals do not simply add all the time. But this is the reality, and it is due to the fact that the relative phase of the two transmitters is different for every overlap. Almost all beacons turn their 457 kHz oscillator off inbetween the pulses in order to save on battery power, and so they come up with a different phase every time the oscillator is switched on. If the signals from two beacons at equal distance have equal phase, the amplitude of the signal will double, if they are opposite in phase, the result is extinction. And all combinations of relative phase are possible, so the receiver gets a rich assortment of signal envelope shapes. But in any case there are edges that can be detected even if the signals overlap, and if interpreted properly, they can help a lot in mitigating the effects of overlap.

Also note that the signals may add in a way that does not affect the overall amplitude. In that case, there will definitely be a change in phase of the resulting signal vector, and this could also be used for purposes of classification.

Another complication to be considered is the fact that overlapping beacons may not transmit at exactly the same frequency. This may lead to periodic amplitude changes during the overlap:

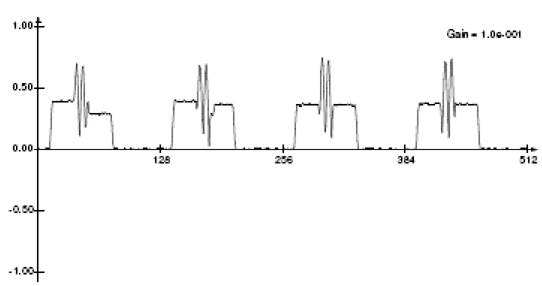

Fig. 2 Effect of frequency difference

In this example, the parameters are the same as in the first one, but with a frequency difference of 20 Hz. Even this situation can be resolved by a good classification algorithm. For larger frequency differences, there is the option of running multiple local oscillators in the receiver, thus obtaining a clean baseband signal for every transmitter that is detected. This, however, is a little more complicated, but feasible and obviously improves performance.

We have found out by experiment that it is possible to detect up to 80% of the edges during overlap. If this information is used in a good classification algorithm, the reliability of a multiple burial resolution algorithm can be improved considerably, and will be much better than predicted in [2].

Obviously, the signal position on the time axis is subject to jumps if a signal originates from a so called "intelligent transmitter". When an intelligent transmitter shifts the position of its transmit pulses in time in order to avoid overlap, the signal edges from such transmitter will no longer fit any existing chain at the receiver, and thus they will be considered emanating from a new transmitter. So focusing on a specific transmitter in a multiple burial situation becomes next to impossible. To this author, it looks like "intelligent transmitters" are not an intelligent thing at all, since they affect the signal that is best suited for handling multiple burial situations.

MARKING

With the above scheme, the marking of a transmitter can never lead to double markings as stated in [2], since a single transmitter will be marked only, based on some chain-specific icon on the display.

COMPATIBILITY

[2] also concludes that beacons that provide signal timing analysis and marking features are not downwardly compatible with the existing base of avalanche transceivers. As we have shown in this paper, this is not necessarily the case. If proper algorithms are used for signal analysis, the problems arising from some properties of the older beacons can be taken care of quite well. We have run many field tests and not noticed a particular loss in performance when searching for older beacons.

Transceivers with large deviations from the 457 kHz standard transmitter frequency do not affect compatibility in terms of multiple burial resolution algorithms. However, as has been shown in [6], they do pose a problem since they require that receiver bandwidths be relatively large in order to accommodate their frequency offset. This in turn has a negative influence on the achievable range when searching for such beacons.

BEACON STANDARD MODIFICATION

We agree with [2] regarding the following items to be considered for the next overhaul of the EN 300 718 [5]:

Beacon pulse periods should be randomized to some extent. This would greatly reduce the probability of long duration overlap situations. It does not affect backward compatibility.

Beacon pulse width should be limited to e.g. 200 ms, since longer pulses increase the probability of overlap. Backward compatibility would not be affected.

The tolerance for the transmitter frequency should be tightened, e.g. to ± 50Hz. This requirement can be met with today's components without an undue increase in cost, and it would permit the construction of better receivers (see [6]). However, since narrowband receivers would then receive signals from transmitters with a larger frequency offset, backward compatibility with old beacons exhibiting a large frequency offset would be affected. A possible approach to this problem may be the introduction of a transition period of several years, similar to the one declared when concentrating on the 457 kHz beacons and abolishing the 2.275 kHz variety.

CONCLUSIONS

Some of the modifications to the standard EN 300 718 as suggested by [2] would really help to handle multiple burial situations by good receiver algorithms.

"Intelligent Transmitters" play havoc with multiple burial resolution algorithms, since they affect the must useful signal feature that can be used for classification.

Contrary to [2], we believe that even in case of signal overlap multiple burial situations can be resolved properly in most of the cases by applying suitable feature extraction and classification algorithms.

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