PROBABILITY OF DETECTION AND SEARCH TACTICAL PROCEDURES IN AVALANCHE RESCUE

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ABSTRACT: The search for a missing person is a race against the clock as survival chances drop very rapidly. The challenge for rescue is to find the proper balance between area search speed and probability of detection. Whereas some search means require a physical hit (probe line), others allow to detect the missing person from a certain distance by an electronic signal (transceiver, EPIRB, Radar), sent (rescue dog), visual (eyesight & IR) or audible. The range of sensing a missing person from distance is influenced by the amplitude of the radiated signal, the sensitivity of the receiver as well as the signal attenuation, reflection and deflection in the media between the missing person and the rescuer. However, success of signal detection is as well influenced by the duration and repeat frequency a signal may be received. Therefore, search strip width (resolution) for most search means is associated with search speed. In avalanche rescue with transceivers the limitation of forward search speed becomes an important factor when the search is carried out by helicopter, on skis, in steep terrain as well as in multiple signal scenarios. To reduce search strip width or search speed independent of the situation leads to an unnecessary increase of burial time and therefore lower survival chances. Thus, the rescuer needs to recognize when a search tactical reduction of search strip width or search speed is indicated and what measures to apply in case the initial search has failed in finding all buried subjects.

KEYWORDS: Avalanche Rescue, Probability of Detection, Survival Chances

INTRODUCTION

It is generic to all search missions, independently of the purpose, search target or environment, that the searching party desires to make a find as quickly as possible. An increase in search times often is associated to reduced survival chances of the party in need or rescue, greater economic loss or increased exposure time of the search party to danger. Thus, the motivation of every search party to reduce search times is obvious.
Faster search velocity however negatively influences probability of detection, which is a critical factor as a miss means that a substantial part, if not the entire search area, needs to be searched again, leading to a very substantial increase of search times.

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Thus, search speed and probability of detection are two competing interests which need to be properly balanced based on the type and goal of the search mission.

The goal of this paper is to list the required measures for avalanche rescue based on signal detection theory and search theory.

SIGNAL SEARCH

1:
Search plane parallel to the surface of the debris:

The larger the search strip width, the shorter the search times and the lower the reduction in survival chances. However as the search strip width increases, the resolution of the search system decreases and thus probability of detection is reduced, leading to additional passages in case of failure.

For all search means which allow to sense the target from distance:

Search strip width recommendations need to be calculated by the manufacturers i.e. for avalanche transceivers are based on ICAR AVA-REC0008 and optimized for greatest survival chances (1).

For dog searches, the dog handler is responsible to adapt the search strategy, including search strip width, depending on scent distribution on the surface.

The probe is the only search mean which does not allow to sense the buried subject from distance, thus considerations on the required resolution of the search system (grid) are only related to the target surface (2).

In order to optimize probability of survival, it is necessary to accept a probability of detection in the first passage which is below 100%. In case of failure, a greater probability of detection can only be achieved by increasing resolution of the search system, thus the search strip or probing grid needs to be reduced in width.

2:
Search plane 90 degrees to the surface of the debris, thus the component of depth:

Burial depth negatively influences the performance of all search means except for the transceiver. As deep burials are not only less frequent, but survival chances are equally lower, a survival chance optimized approach always sets priority to the top layer, approximately the first 1.5 m of depth of the debris.

The range of high frequency search devices (Recco, GSM, GPR) is negatively influenced if the waves need to penetrate liquid water or a moist snowpack. As the snow temperature increases, the greater is thus signal attenuation and therefore the size of the area on the surface of the debris in which the signal can be detected decreases.

Dog searches require the scent to raise to the surface of the debris. Permeability and scent attenuation is dependent on the characteristics of the debris, influencing in what rate the scent cone may raise, and the residual molecule concentration at the surface. Increased burial depth thus increases the delay for scent molecules to raise to the surface and lowers the concentration of scent molecules.

In probe searches, search times increase considerably (3), when the probing depth increases.

In case of increased burial depth, probability of detection decreases in the first passage for all search means suffering from reduced performance due to signal attenuation in the debris. The appropriate search tactical reaction to the fact that the size of the area on the surface of the debris where a signal can be detected, is to increase the resolution of the search system and thus to shrink search strip width. For search means with a directional characteristic, i.e. Recco, the reduction of search strip width furthermore leads to greater focus on vertical penetration of the debris.

In probe line searches, probing depth is therefore increased in the second passage of course probing and again in fine probing (4).

The range of all search means applied in avalanche rescue is limited by the horizon given by soil and rock of the terrain below the debris. In very uneven terrain, rescuers must respect that the search strip width always is limited to terrain shading. As a simple rule of thumb, a surface which is not in direct line of sight of the rescuer, should never be considered as searched, independently of search strip width. For harmonic radar (Recco), certain soils and rocks containing metal oxides have a reflecting characteristic which is relevant in cases where the depth of the debris is very shallow.

3:
Search speed:

Search speed influences for how long a signal may be received. Probability of detection is influenced by signal duration and thus very high search speed should be avoided. Critical limits can in particularly reached when searching on skis, from a vehicle or in an airborne search.

When searching for an intermittent signals, such as from a transceiver, it is possible to pass an area in which the signal would be detectable in a period of time when no signal is transmitted. The ETS 300718 legal standard for avalanche transceivers limits the longest possible period length to 1.3 sec and the shortest possible pulse length to 70 ms, thus the longest pause is 1230 ms. For airborne transceiver searches to be reliable, the maximum allowed true ground speed is 7 kn, thus 3.6 m/s, within the longest possible pause, the helicopter thus moves 4.5 m. On skis, in particular in tree well related searches, a the forward speed of an unaware searcher may easily reach 30 km/h,

thus the rescuers moves 10 m within the longest possible pause.

4:
Strong interference:

Strong interference inhibits the detection of weak signals as they are lower in amplitude than then interfering signal. As a search tactical reaction, search resolution needs to be increased. Due to the narrowed search strip width, the rescuer passes each buried subject in a distance which is sufficiently short to ensure that the amplitude of the transmitter of the buried subject clearly overcomes the amplitude of the interference and thus allows the transmitter to by located.

COARSE SEARCH

1:
Speed vs. precision:

The requirement for search precision increases with decreasing distance to the buried subject, thus the search speed needs to be lowered the closer the rescuer gets to the target.

2:
Multiple signals:

In case multiple burials are present within the range of an electronic search device, it is only possible to separate one from another if the signals show, at least during some periods of time, distinctive characteristics. This is only given for avalanche transceivers, as the period and pulse length, and their position on the time axis is not equal for all of them. All modern devices use pattern detection algorithms to distinguish signals from the different buried subject's transmitters. The greater the number of transmitters and the longer their pulse length, the greater is the probability for frequent and persistent signal overlap. During signal overlap, signal detection is compromised which may lead to an incomplete list of buried subjects. When the rescuer remarks that a transceiver search in standard search mode for multiple buried subject becomes impossible or highly inefficient, an alternate search strategy needs to be applied.

Alternate search strategies in transceiver search take signal strength as separation criterion. In order to ensure that each buried subject can be reliably fond, the resolution of the search system is increased until the amplitude of the transmitter of each missing buried subjects clearly overcomes the amplitude of the previously overlapping signal, allowing the transmitter to by located. Stepping up search resolution more and more reduces search strip width. The 3-circle method and the static (elementary) micro search strip method apply a fixed search strip width of 3 m, the dynamic micro search strip method allows to adapt the resolution with search strip widths between 2 and 5 m. The highest resolution is possible by applying the micro box, where there are no limitations in how narrow the search strip with may become.

Due to the highly directional characteristics of Recco, multiple burials with Recco reflectors may be differentiated from each other by different angles for signal reception. This approach is faster (= 1st choice) than reducing search strip width, but depending on proximity between buried subjects and reflector orientation may not always be successful. In such cases, following the approach of alternate search systems for transceivers, the amplitude criteria is taken as reference and the same strategies applied as described above.

FINE SEARCH

1:
Precision requirement:

Burial time is mainly influenced by the time it takes to excavate the buried subject. With an average excavation performance of 140 liters / rescuer / minute, there is no tolerance for an unnecessary increase of excavation volume. Thus, searches optimally end with no uncertainty about the find, a level of confirmation which is usually achieved by a physical probe hit.

The preferred technique, spiral probing, applies a 25cm resolution. Length and width of the pinpointing area increases with factor two relative to the imprecision in fine search, the relevant surface thus increases square to the double of the residual imprecision. Fine search precision should thus be better than 50cm.

2:
Sequence of axis in perpendicular alignment:

For a "spot-on landing", either approaching in a straight line or on a radius, a hard criterion on fine search precision requires that the forward and angle velocity tends towards very low values and very low thresholds for incompliance to the indications given be the search devices.

As these requirements are unrealistic, the fine search is carried out as a series of axis in a rectangular alignment, cutting the potential surface in half with every additional axis until the required fine search precision criteria is met.

CONCLUSION

Probability of detection and area search speed are two antagonists, which need to be properly balanced to maximize the survival chances of those ones in need of rescue.

1:

Search speed should be reduced in the following situations:

- in close proximity to a search target (all electronic search means)
- in complex search areas due to the number of buried subjects (all electronic search means)
- in presence of interference (all electronic search means)

As soon as none of the above criteria are meet, search speed needs to be increased.

Search strip / grid width should be reduced in the following situations:

- when the search in a standard search mode fails (transceiver)
- in presence of interference (all electronic search means)
- when not all buried subjects are found in the previous passage, search the immediate vicinity (10m) around previously found buried subject again with reduced search strip width (all electronic search means)
- when not all buried subjects are found in the previous passage, search entire surface again with reduced search strip / grid width (all search means)

As soon as none of the above criteria are meet, search strip / grid width needs to be increased.

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