# Statistical analyses on multiple burial situations and search strategies for multiple burials

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## Abstract:

Recent statistical analysis based on 466 skier triggered avalanches in Switzerland from almost 30 years (winter 1970/71 to 1998/99) causing 698 completely buried people show that a surprisingly high percentage of victims get caught and completely buried in avalanches producing multiple burial situations. The analysis where focused on victims which could not be found by visible parts, so all of them clearly match the criteria for transceiver search. This surprisingly high percentage is an important sign for the importance of the multiple burial criteria in transceiver training, in testing, as well as in the further development of transceivers and specialised training solutions.

The transceiver search for multiple burials always presents lay and professional rescuers with a difficult task. Manufacturers suggest various, transceiver technology specific search approaches, which makes training demanding and time consuming.

The proposed search approach requires, on the one hand, a thorough analysis of the burial situation, and on the other, a systematic search procedure that can be applied in any situation and independently of the transceiver technology. This systematic way makes the system teachable and therefore learnable. The experience in the field of transceiver based pinpointing systems for deep burials has already shown that many experienced and professional rescuers have developed their own, for themselves highly efficient search strategies. However, it is often very difficult to formalise such highly individualistic approaches in order to make them available to a wider public.

The thorough and continuous analysis of the burial situation tells the rescuer at any time how many victims there are in which radius around him. This information allows to define an appropriate search strategy.
The systematic search procedure is based on the idea that a clear signal isolation makes locating an avalanche victim easier for human ears with an analogue transceiver - but as well for a digital transceiver. Taking differences in signal strength as criteria to separate the different transmitters from each other, all zones where one individual signal is significantly stronger relative to the other signals have to be discovered. This situation can be found where the rescuer is close to a certain victim relative to the others.
Applying the micro search strip search strategy the searcher systematically scans the potential area for those zones close to transmitters where one signal is significantly stronger than the other ones.
The more victims there are and the closer they are together, the narrower is the micro search strip width:
The strip width is reverse proportional to the spatial density of the burials.

**Keywords:** avalanche accident, avalanche incident, avalanche accident statistics, avalanche rescue, transceiver search, multiple burials

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## 1. Recent statistical analysis of avalanches causing multiple, completely buried victims

Recent statistical analysis based on 466 skier triggered avalanches from almost 30 years (winter 1970/71 to 1998/99) causing 698 completely buried people show that a surprisingly high percentage of victims get caught and completely buried in avalanches producing multiple burial situations. The analysis where focused on victims which could not be found by visible parts, so all of them match the criteria of transceiver search. 280 avalanches out of the 466 where trigged in backcountry skiing terrain (ski touring) , while the remaining 186 occurred during out of bound (off piste) skiing. 61% of all backcountry skiers who could not be found by visible parts were involved in a multiple burial situation. 26% of all backcountry skiers, *more than every forth*, who could not be found by visible parts were part of a 4 or more burial situation! 13,6% were in a 5 or more burial situation, 8,3% in a 6 or more, 3,2% in a 7 or more and finally 1,7% in a 8 burial situation.

The distance between the burial locations is not known. However, it is known in almost all the cases if the group was ascending or skiing downhill when they triggered the avalanche. As expected, in those cases which produced a high amount of burials (5 or more), the groups where almost always ascending and got caught as a group. It is therefore very likely that the group was not too much spaced out between each other and was carried downhill and buried in a very similar constellation they were ascending. Therefore, the likelihood that they created a situation with multiple burials in close proximity is fairly high.

Even tough the percentage of accidents causing a high amount of completely buried victims is fairly low looking at all avalanche accidents, one clearly has to state that **IF** a transceiver search is necessary - because the victims can not be found by visible parts - the chance that many victims have to be searched for is much higher than previously expected.
If a **backcountry skier** claims to be able to **find 90%** of all victims, still leaving out every tenth - then he **must be able to solve a 6 burial scenario.**
If he is **not able to solve a 4 burial scenario,** he would **not have found 25% of all victims - every forth!**

Looking at all accidents in the backcountry with completely buried victims that can not be found by visibly parts, 35% cause multiple burial situations.

Compared to out of bound skiers, the group of back country skiers is much more likely to be involved in a situation with a high amount of victims. This is manly due to the bad habit of back country skiers to travel in large groups.

Looking at out of **bound skiing accidents**, the amount of avalanches causing multiple burial situations drops to 16%.
If a **out of bound skier** claims to be able to find 90% of all victims, still leaving out every tenth - then he must be able to **solve a 3 burial scenario.**
If he is **not able to solve a 2 burial scenario**, he would **not have found 31% of all victims - almost every third!**

| | off-piste | ski touring |
|---|---|---|
| x burials | y % not found | y % not found |
| 1 | 100.0 | 100.0 |
| 2 | 31.3 | 61.2 |
| 3 | 11.0 | 40.3 |
| 4 | 4.4 | 26.3 |
| 5 | 4.4 | 13.6 |
| 6 | no cases | 8.3 |
| 7 | no cases | 3.2 |
| 8 | no cases | 1.7 |
| 9+ | no cases | no cases |

Table 1: If you are not able to solve a x-amount burial scenario, you would not have found y % of all victims!
Backcountry / ski touring: 100% = 471 victims
Out of bound / off-piste skiing: 100% = 227 victims

All those surprisingly high percentages are an important sign for the importance of the multiple burial criteria in transceiver training, in testing, as well as in the further development of transceivers and specialised training solutions such as radio controlled transmitters.

| | ski touring | | | | off-piste | | | | total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| amount of burials | amount of accidents | % | amount of affected persons | % | amount of accidents | % | amount of affected persons | % | amount of accidents | % | amount of affected persons | % |
| 1 | 183 | 65.4 | 183 | 38.9 | 156 | 83.9 | 156 | 68.7 | 339 | 72.8 | 339 | 48.6 |
| 2 | 49 | 17.5 | 98 | 20.8 | 23 | 12.4 | 46 | 20.3 | 72 | 15.6 | 144 | 20.6 |
| 3 | 22 | 7.9 | 66 | 14.0 | 5 | 2.7 | 15 | 6.6 | 27 | 5.8 | 81 | 11.6 |
| 4 | 15 | 5.4 | 60 | 12.7 | 0 | 0.0 | 0 | 0.0 | 15 | 3.2 | 60 | 8.6 |
| 5 | 5 | 1.8 | 25 | 5.3 | 2 | 1.1 | 10 | 4.4 | 7 | 1.5 | 35 | 5.0 |
| 6 | 4 | 1.4 | 24 | 5.1 | 0 | 0.0 | 0 | 0.0 | 4 | 0.9 | 24 | 3.4 |
| 7 | 1 | 0.4 | 7 | 1.5 | 0 | 0.0 | 0 | 0.0 | 1 | 0.2 | 7 | 1.0 |
| 8 | 1 | 0.4 | 8 | 1.7 | 0 | 0.0 | 0 | 0.0 | 1 | 0.2 | 8 | 1.2 |
| **total** | 280 | 100 | 471 | 100 | 186 | 100 | 227 | 100 | 466 | 100 | 698 | 100 |

Table 2: Number of accidents and affected people for multiple burials (completely buried people found without visible parts from 1970 to 1999).

## 2. Introduction to search strategies for multiple burials

The transceiver search for multiple burials always presents lay and professional rescuers with a difficult task. Manufacturers suggest various, transceiver technology specific search approaches, which makes training demanding and time consuming.

The proposed approach requires, on the one hand, a thorough analysis of the burial situation, and on the other, a systematic search procedure that can be applied in any situation and independently of the transceiver technology. This systematic way makes the system teachable and therefore learnable. The experience in the field of transceiver based pinpointing systems for deep burials has already shown that many experienced and professional rescuers have developed their own, for themselves highly efficient search strategies. However, it is often very difficult to formalise such highly individualistic approaches in order to make them available to a wider public.

## 3. A systematic analysis of the burial situation

### 3.1 How many victims are there within which radius?

In searching for multiple victims, it is fundamental to be aware of the entire situation. The first question is: *"how many victims are there within which radius?"* As this set of information is only valid relative to a specific geographic location, evaluation is a continual process.

In the following diagram (ill. 1) the rescuer is approaching three buried victims. The triple beep indicates the number of victims, the distance indicator or the setting of the sound level (sensitivity), gives a rough indication of the radius in which those victims are situated. By getting closer and closer to the first victim (ill. 2), the rescuer will in the end, only hear a single beep sound. This indicates there aren't any another victims in the immediate vicinity. For the victims two and three (ill. 3) the situation is different. Even though the distance indicator reaches only two (or the sensitivity (volume) setting is very low), there are still two beep sounds. The rescuer then knows that there are two victims in close proximity.

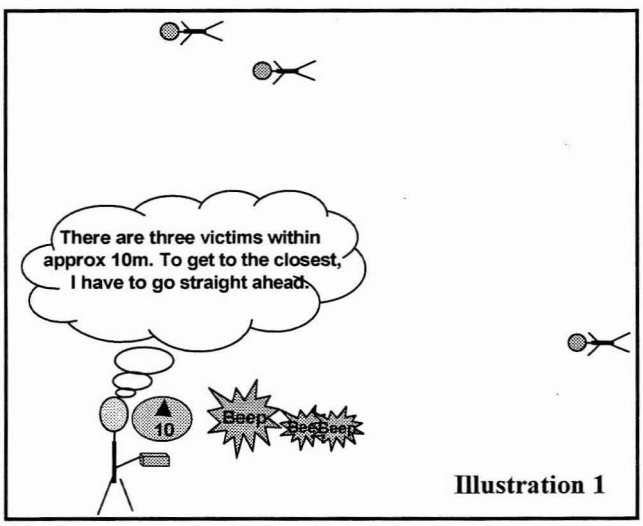


Illustration 1

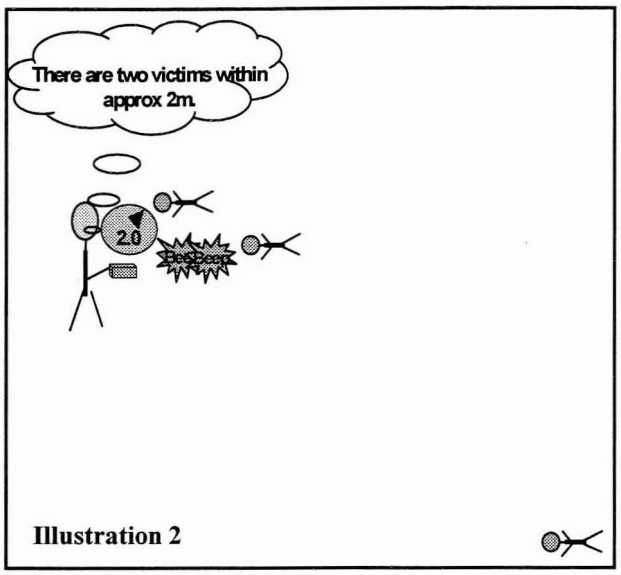


Illustration 2

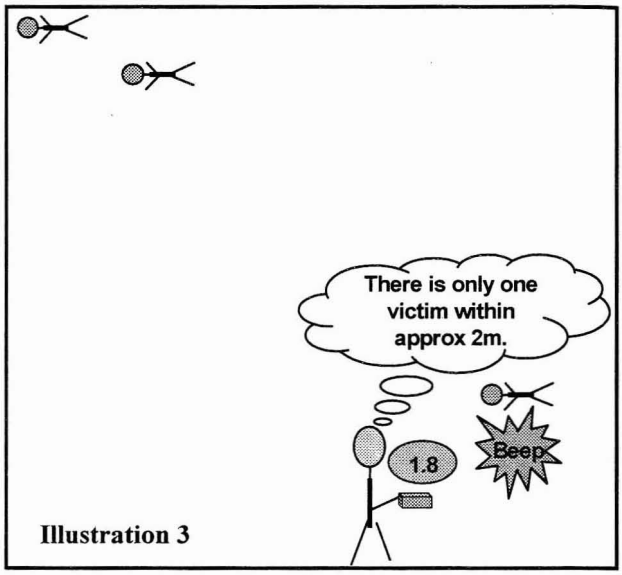


Illustration 3

### 3.2 Analogue or digital ?

To answer the question: *"how many victims are there within which radius?"* the number of victims and their distance to the rescuer must be available simultaneously and at all times. This set of information is only valid relative to a specific location on the avalanche. Digital only transceivers, can with today's display units only show information about one single victim at the time. This is a serial way to present an information. The rescuer who is continually moving on the avalanche cannot readily asses the entire situation as not all the necessary information is simultaneously available. On the other hand, transceivers with analogue search mode provide the rescuer on average every second the complete set of information simultaneously – and therefore it is fully valid for the current location of the rescuer.

Traditional analogue transceivers require a considerable amount of training as all the necessary search information (distance, direction, amount of burials) needs to be interpreted based on the analogue sound. Digital transceiver technology allows to calculate and display distance (single antenna devices) or distance and direction information (dual antenna devices) - this makes interpretation much easier for the user. However, regarding the processing of multiple signals, the human hearing abilities are still much stronger that what today's digital transceiver technology is able to do.
Why? The sound patterns which all of us have to analyse every day have clear similarities with what we face in a multiple burial situation:

- a group of people is talking and you are still able to concentrate on a single voice.
- you are in a bar with loud music - everybody is talking - but you are still able to concentrate on a single voice.

They show how powerful the human hearing abilities are in analysing sound patterns and filtering out the relevant information.
Manufacturers are trying hard to improve their digital transceivers for multiple burial problems. The success of their efforts is as well heavily depending on what becomes available on the integrated circuit and microprocessor market and meets their specific needs concerning power consumption, performance and finally as well the price.
In the mean time, it is a very good alternative to combine already reliably realised features of digital technology and still taking advantage of some specifically strong points of our human hearing abilities. Such digital/analogue devices provide visual information as well as traditional analogue sound. There are several digital/analogue devices available on the market. The only thing the rescuer has to be able to do with the analogue sound is to count the amount of signals. All the other information (like distance indication) is given on the screen and does not have to be derived of the analogue sound.

In the future, the percentage of digital technology in a transceiver will increase - and some day it might be possible to fully replace the analogue part without any disadvantages. However, for a successful, fully digital approach the way how digital transceivers exchange information (i.e. the length and frequency of the transmitted pulses) would have to be optimised for digital transceiving systems. If such a change will be backward compatible to already existing transceivers, can not be conclusively answered at this time.

## 4. The main problem are multiple burials in close proximity

When victims are buried in different search strips (primary search), they will not be detected by the transceiver at the same time. In such a situation there is in fact a multiple burial situation on the avalanche, however concerning the transceiver search, it is a step by step single burial search. If there are two victims within the range of the transceiver, but far apart of each other, the situation can as well be solved rather easily. The main difficulty clearly is, to locate several victims in close proximity to each other.
Diagram 1 illustrates the typical situation in such cases: several transmitters are received more or less at the same amplitude. Human hearing as well as a microprocessor do not have the ability to clearly distinguish the signal of one transmitter from that of another in this situation. But precisely this is necessary to be able to locate an avalanche victim.
By contrast, in diagram 2, one signal is considerably louder than the others. In this situation it is easier for our hearing and for a microprocessor to isolate this specific signal, permitting the rescuer to locate the victim fairly easy.

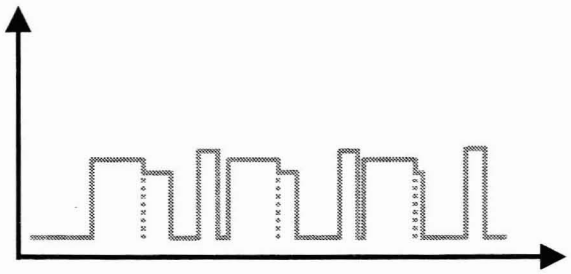

**Diagram 1**

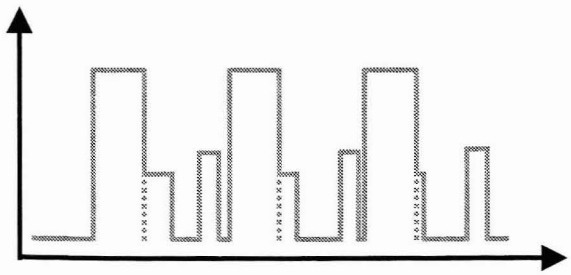

**Diagram 2**

### 4.1 Micro search strips as systematic search method for several closely buried victims

In developing a systematic search method for several closely buried victims, I have where possible, refereed back to already established concepts that are part of every standard transceiver training. I took the search strip principle as elementary concept. Only the width of the search strip needs to adjusted to the given situation.
As described in the previous section, it is almost impossible to systematically solve a scenario like described in diagram 1 by a deliberate search. The micro search strips make it possible to the rescuer, through a systematic approach, to achieve a easy to solve situation like shown in diagram 2.
As always, the rescuer analyses how many victims there are in which radius around him. The more victims there are and the closer they are together, the narrower is the micro search strip width. Technically speaking, the width of the search strip decreases proportional to the increase of density of victims in their spatial distribution.
The diagram 3 illustrates a fictive search pattern as applied to a potential search area. The blue markings indicate areas which provide unfavourable signal patterns, as described in diagram 1. On the other hand, the areas of the white circles denote a situation as described in diagram 2. The victims can fairly easy be located independently of the transceiver technology within this circles. Adapting the micro search strip width to the actual situation ensures that all those areas will be discovered.

### 4.2 Practical approach

After evaluating the number of victims in a certain area, the rescuer determines the micro search strip width. Usually the width is between 2 – 5 m. During the search process, hold the transceiver always in the same orientation close to the snow surface and concentrate on the increase and decrease of the distance indication, respectively to the volume of the analogue sound. The final localisation is carried out by applying a classical orthogonal search. Here also, the orientation of the device must be kept always in the same orientation.
Direction indications, where available, should be completely ignored in this phase. Multiple burials in close proximity produce field line patterns which become so weird that it is not anymore possible to reliably follow a specific field line.

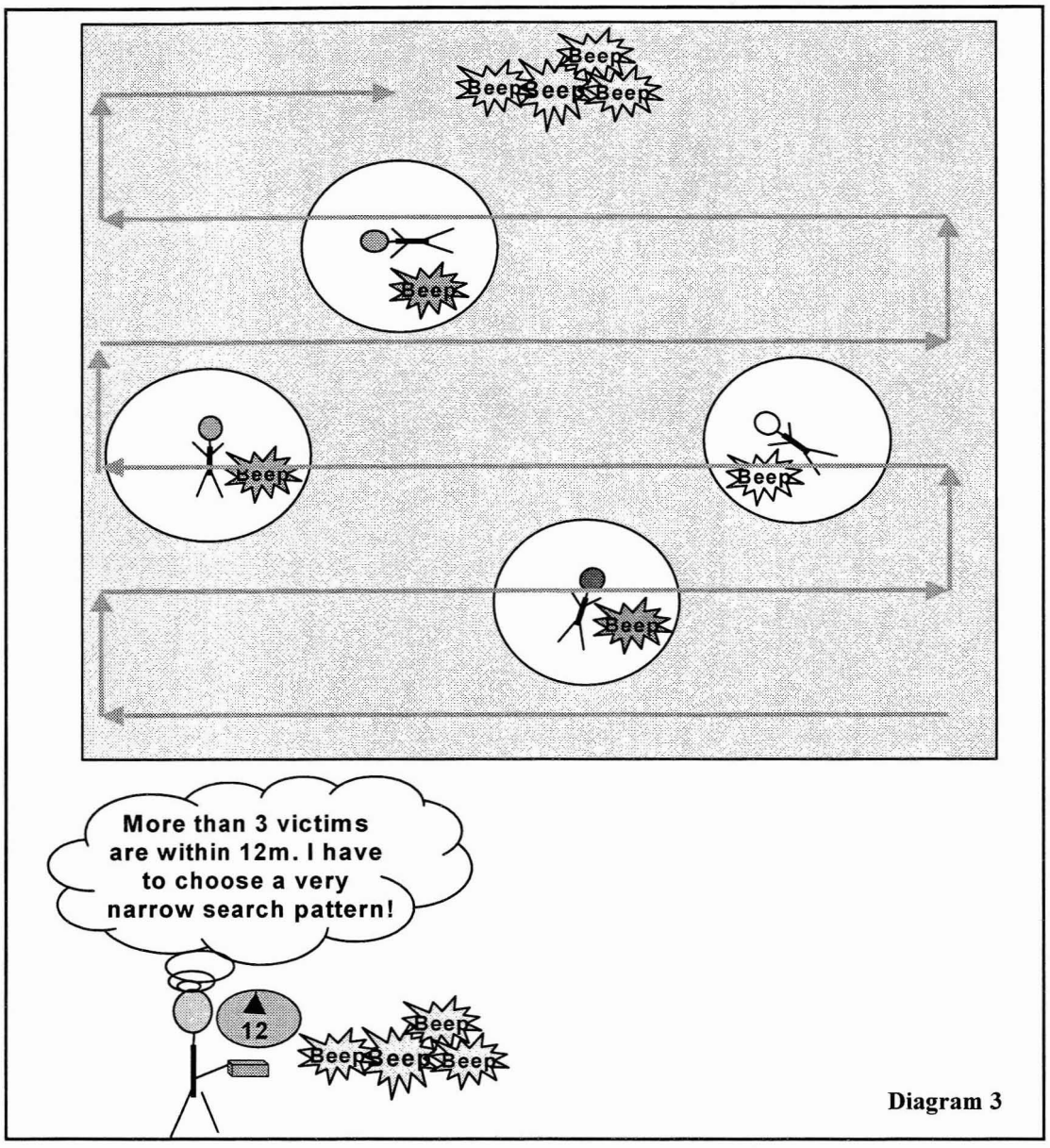


Diagram 3

It is important not to stray away from the systematic search path towards seemingly obvious targets or impressions of them. In the case of several closely buried victims the situation becomes so complex and misleading that any inconsistencies to the systematic approach lead to confusion and a waste of time.
When publicly demonstrating this search system, I was sometimes tending to leave the systematic search pattern and take an *expert's short-cut* in order to be even faster - however too often without success – that's why I don't even try anymore...
The dimensions of the area to be searched with the micro strip pattern is determined in the following way: should the distance indicator only increase or the volume of the analogue sounds only get fainter, the rescuer has reached the borders of the area.

**4.3 What does the micro search strip strategy have in common with conventional methods?**

Until recently rescuers have, after locating a victim and independent of the transceiver technology, consciously moved away from this first victim before they where able to search for further victims. This "moving away" (from the strongest signal) was in an accidentally chosen direction as the location of the he next victim is obviously still unknown at this time. With the micro strip search pattern "moving away" in an accidentally chosen direction is replaced by a systematic search of the area. This reduces the possibility of missing a victim or returning to victims which have already been located: It increases the over all reliability of the search.

### 4.4 How to search with transceivers without analogue sound

The micro search strip system can as well be used with transceivers which do not anymore provide an analogue sound. Some specific limitations are discussed in paragraph 2.2 "Analogue or digital" and concern mainly how the rescuer can get a reliable image of the burial situation. The answers to the main question: "How many victims are there within which radius?" is presented to the rescuer in average every second by listening to the analogue sound. On the other hand side, a rescuer using a digital only device has to stand still and slowly rotate the device 180°. By counting the different distance/direction indications given on the screen he can try to find out how many victims there are in which radius. The process of locating the victims within the micro search strips is exactly the same as with other transceivers, however, the importance of having a good general impression of the search scenario at all times when searching for multiple burials is unquestionable.

### 4.5 How to proceed when there are multiple deep burials?

This situation is probably the most complex one, especially if the different burial depths are widely varying. It is important that you always solve the multiple burial problem before you solve the deep burial problem - and at a certain point probing always starts to be an legitimate mean. However, one should always keep in mind that probing can take an enormous amount of time - especially when only a few probes are available. If enough rescuers are available - which is probably only the case in organised rescue - you can always use the two means (probes and transceivers) at the same time. In companion rescue, however, one often has to decide on a single search mean - and when you decide to stop the transceiver search an proceed with probing, you often loose track of what happened in transceiver search. An eventual step back to the transceiver might become very time consuming.
One always has to take into account that only a very few people where found alive by probing. Furthermore, the probes do not penetrate the snow pack in a straight line which means in case of deep burials, that search precision and reliability of this mean of rescue is again reduced.

## 5. Technical remark on the use of the term "distance indicator"

In this article the term distance indicator is used. In fact it actually is an indication of a tendency. Specially single antenna devices give values, which, depending on the relative orientation between the transmitter's and the receiver's antenna, may widely vary from the real distances.
Basically the precision improves with decreasing distance to the transmitter. In the case of several buried victims in close proximity we are generally in an area where the transceivers produce fairly reliable results.

## Notes: