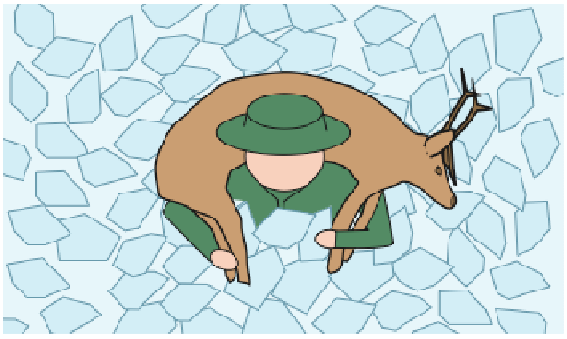
Title: **The Avalanche Airbag System and modern Avalanche Transceivers. Useful rescue devices with gadget functions?**

Author: Franz Kroell[1]
1. Manufacturer, Munich, Germany

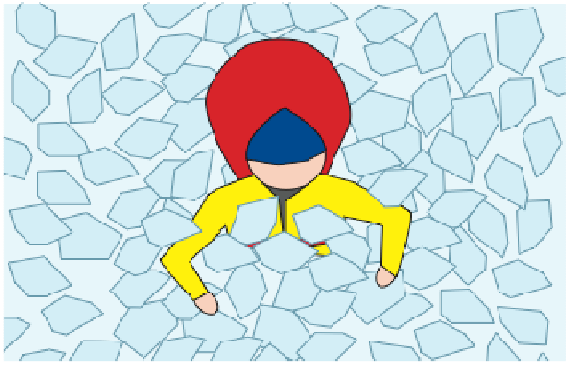
This document reviews the effectiveness of the Avalanche Airbag System and Avalanche Transceivers.
Essential design concepts of the Avalanche Airbag System and triggering systems (remote controlled triggering) are presented and compared.

Avalanche Airbag System

In 1973 a revolutionary idea for avalanche survival was born when the hunter and forester Josef HOHENESTER realized that he could stay on top of an avalanche while carrying a chamois buck on his shoulder.



He had contrary experience from previous events with avalanches. The idea behind his survived ride was: While transported by the avalanche, increase your volume and you will stay on top of the avalanche!



HOHENESTER applied for the patent "Device for indication of position and for self-rescue of a person in an Avalanche" ("Gerät zum Anzeigen und zur Selbstrettung seines Trägers in Lawinen.").
It took almost 25 years for users, responsible organisations, guides, rescuers and opinion leaders to realize the potential of this revolutionary idea.
A single warrior – Mr. Peter ASCHAUER - fought almost two and a half decades to get this live-saving idea across to the backcountry community.

Avalanche Transceivers

Avalanche Transceivers have been on the market since the late sixties. 1+ million Transceivers are in use worldwide; more than 50% of these devices have been in use without any check for centuries!
Avalanche Transceivers are designed to save lives. Live-saving devices need service. Avalanche Transceivers should be sent to the manufacturer for periodic tests.

Avalanche Transceiver technology has changed a lot over the last two decades.

Intuitive design and user interface, multi-antenna technology for easy directional and fine search, accurate signal analysis and flagging to solve multiple burial scenarios, automatic safety switch back for personal protection in case of a secondary avalanche and new software for update are the main steps in Transceiver evolution.

Signal of Avalanche Transceiver

Avalanche Transceivers should transmit on frequency 457 kHz (+-80Hz) according to the EN standard 300 718-1, -2, -3.
Duration of the pulse needs to be 70ms [milliseconds] minimum; the OFF-time between two signals should be 400ms minimum; the period of the signal (cycle) should be 1000ms +-300ms (=ON-time plus OFF-time).

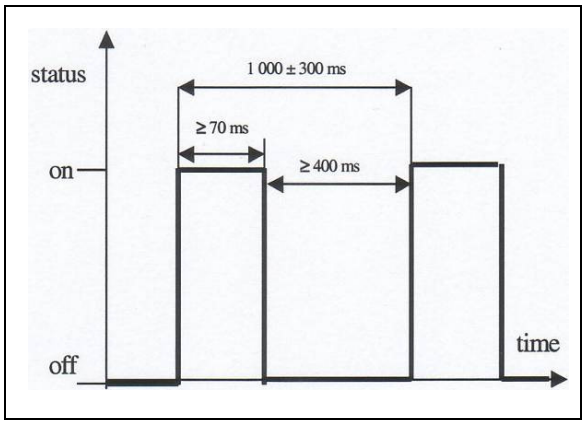


Diagram (1)
Duration of pulse 70ms [milliseconds] minimum
OFF-time: 400ms minimum
Period of signal (cycle): 1000ms +-300ms (=ON-time plus OFF-time).

Accurate signal analysis

According to statistics from Genswein, a significant number of captured and buried persons are part of a multiple burial scenario. Modern Avalanche Transceivers should be capable of solving multiple burial scenarios. This requires professional training AND high-tech transceivers.
Accurate signal analysis is the key-function for solving multiple burial scenarios. While perfectly trained ski patrollers and professionals may also be able to solve multiple burial scenarios with analog transceivers, the majority of users likes the digital help of reliable signal analysis and flagging function.

Accurate signal analysis is a process of maximum precision, consisting of measuring the essential signal parameters and creating the "finger-print of the signal":

- duration of the pulse [measuring the flanks of start and end of the pulse; measuring duration of pulse],
- OFF-time [pause] and
- period of the signal [ON-time plus OFF-time]

The individual "finger-prints" of all signals needs to be combined and calculated.

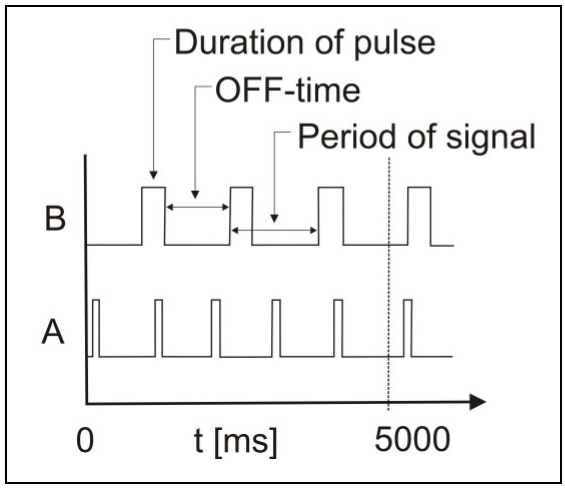


Diagram (2): *"Finger print" of a signal with short duration [A] and with a long duration and long period [B].*

In case of signal overlap the searcher needs to get reliable information.

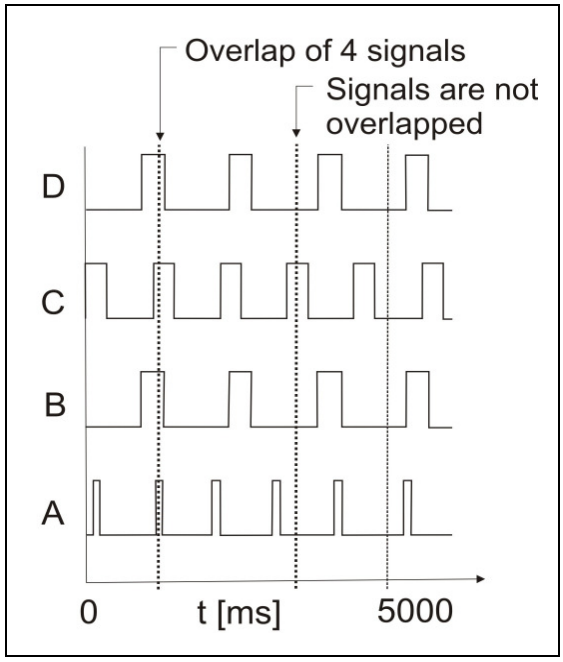


Diagram (3)
"Fingerprint" of 4 signals – signals overlapping (left), signals not overlapping (right)

In case of such a massive overlap even very sophisticated, modern Transceivers are driven to their limits – at least for a few seconds. Once the signals do not overlap the searcher can continue.
Overlapped signals cause chaotic patterns for a very short time. These chaotic patterns cannot be tracked.
Results of overlapped signals are mostly not useful – whether they are generated by digital or analogue signal. Overlapping

signals may delete each other or half their signal strength or increase it.
Experience from transceiver trainings shows that accurate signal analysis and reliable flagging is the key to solve multiple burial scenarios.
Accurate signal analysis and reliable flagging is an essential function of today´s high-end transceivers.
Even novices can solve multiples with modern Avalanche Transceivers providing accurate signal analysis.

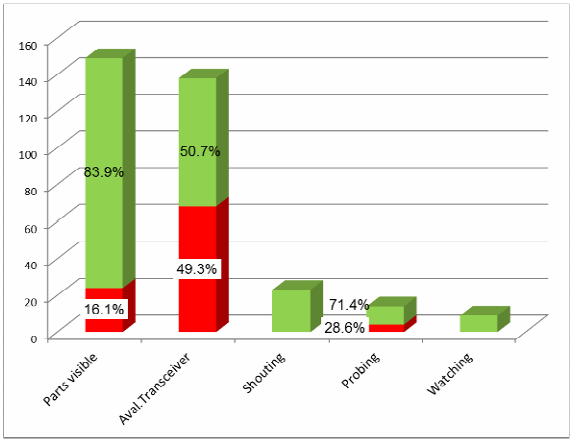


Diagram (4) *- Companion rescue,*
Survival rate (83.9%) when parts of the victim's equipment is visible.
Survival rate (49.3%) when using Avalanche Transceivers only.
Source: SLF-Davos

Effectiveness of Avalanche Rescue devices

Basic "instruments" like education by Avalanche professionals, careful route and terrain selection, snowpack evaluation including intensive testing, perfectly adapted behaviour, skiing one by one in steep terrain, using physical methods – or using the so-called strategic methods – may provide a certain degree of protection for a backcountry skier, snowboarder, snowmobiler and helicopter-skier from most avalanches.

The remaining rest of the risk needs to be covered with effective equipment.

To be fully buried by an Avalanche without using Avalanche Rescue gear like Airbag plus Avalanche Transceivers, probes and shovels is lethal in almost 100% of the cases.

Effectiveness of Avalanche Transceivers

Swiss statistics (SLF-Davos) show the effectiveness of Avalanche Transceivers in the period from 1980 – 1999.
Companion rescue with Avalanche Transceivers provides a survival rate of approximately 50%.
Visible parts of victims provide a higher survival rate, almost 84%.

Use and worldwide sales of Airbags and Avalanche Transceivers have increased over the last two decades from approximately 40 000 units per year (1990) up to approximately 160 000 units per year in 2012.

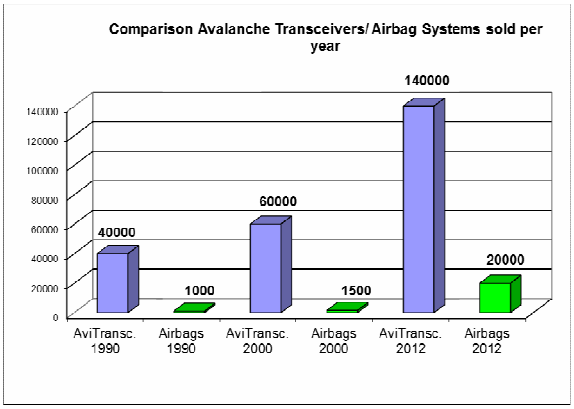


Diagram (5): *Worldwide sales of Avalanche Transceivers and Airbag Systems per year.*

Acceptance, sales and use of Airbag Systems has increased over the last two decades from approximately 2500 units in 1990, up to 10 000 units in 2000 and up to 20 000 units in 2012.
Worldwide approximately 150.000 Airbags and 1+ million Avalanche Transceivers are in use.

Effectiveness of Airbag Systems

It is obvious: The backcountry community has to decide carefully when it comes to new technology. Some of the arguments by

which the community tried to explain that the Avalanche bag

- may increase the level of risk,
- is to heavy and to bulky,
- is too expensive and
- it may not work 100%.

Level of risk

Risk compensation caused by better equipment is a long-discussed and well-known phenomenon in the mountaineering community. Better sport equipment may increase the level of risk by an unimportant number. Better skis, far better skiing technique and stronger snowmobiles allowing faster and more frequent access to more exposed areas with changes in the lifestyle of the skiing and snowmobiling community may really increase the level of taken risk.

Weight

Less than 2000 grams for a proven life saving device is not that much extra weight.

Cost

700 up to 990 $ is easily more than compensate for a life.

Rate of success

The rate of success for inflated Airbags is at the level of 97%.

Visibility and rate of burial with Airbag System

Out of a sample of 262 persons with inflated ABS airbags involved in avalanche accidents statistics show that 97% of this sample are visible on the debris – only 3% are not visible.

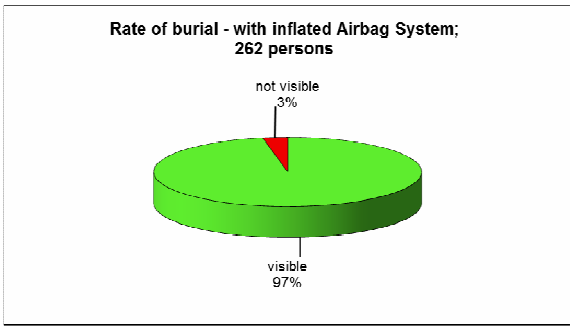


Diagram (6): *Visibility and rate of burial WITH inflated Airbag System. 97% of captured persons are visible.*

Visibility and rate of burial without Airbag System

Out of a sample of 67 persons involved also in the above avalanche accidents the rate of burial without Airbag was significantly higher: 57 % are visible and 43 % are NOT visible.

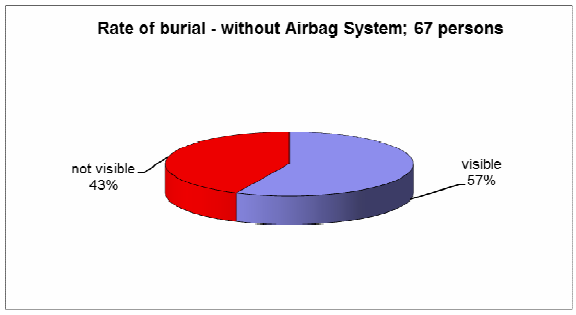


Diagram (7): *Visibility and rate of burial WITHOUT Airbag System. Approximately half (= 57%) of the captured skier are visible.*

Rate of survival WITH Airbag System

The rate of survival with Airbag Systems (sample: accidents with 262 persons with inflated ABS airbags involved) is the highest by far compared with the other existing avalanche safety and rescue tools; it is 97% survivals and 3% non-survivals. Moreover, a fairly high number remained uninjured: 84%.

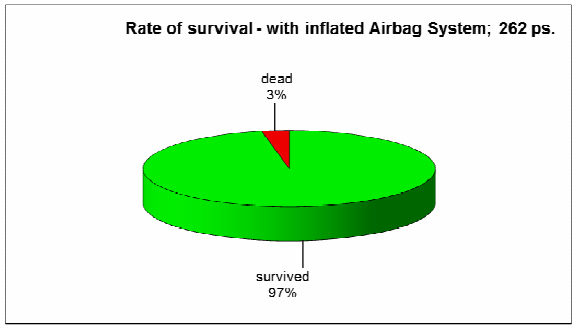


Diagram (8): *The rate of survival WITH inflated Airbag System is pretty convincing: 97%.*

Rate of survival WITHOUT Airbag System

Exactly the same accidents mentioned above also involved 67 people without Airbag System. Out of these 67 persons, 15 did NOT get buried, 23 were partly

buried, 29 were completely buried; 1 persons situation is unknown.

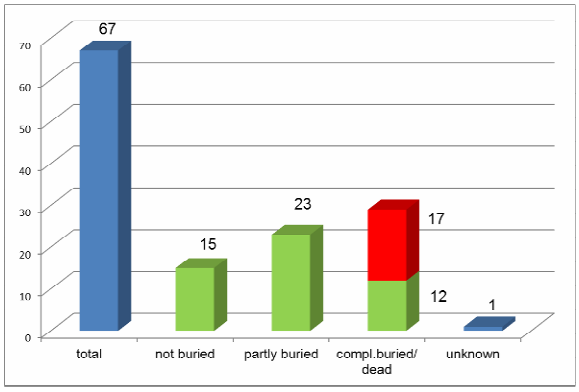


Diagram (9): *67 persons are caught by an avalanche; 29 got fully buried; 17 persons died out of these 29.*

Out of this sample of 67 persons, 75% (= 50 persons) survived and 25% (17 persons) did not survive the incident.

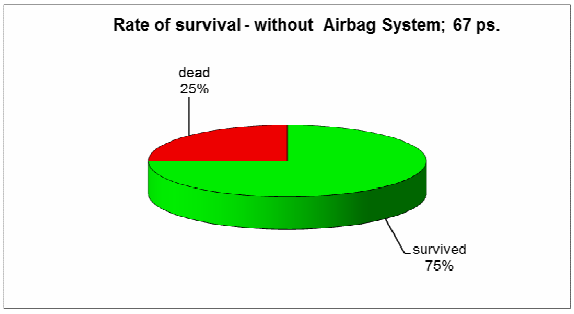


Diagram (10): *Rate of survival WITHOUT Airbag System, using Avalanche Transceivers = 75%.*

Using an Airbag may increase the chance of survival by eight times.

Latest statistics (August 2010)

The graph below shows the 97% success rate of 249 documented Avalanche accidents with 295 persons involved using ABS Airbags.

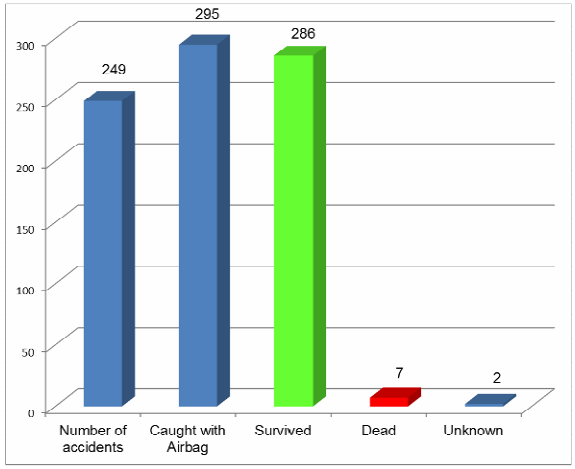


Diagram (11): *Out of 295 persons using the ABS Airbag System involved in 249 documented avalanche accidents, 286 survived (= 97% success rate), 7 got killed and 2 incidents are unknown. Source: SLF, Davos*

Function of Avalanche Airbag

Comparing the weight per litre of (Avalanche)-Snow and of a human shows a big discrepancy.
100 litres of (Avalanche)-snow correspond to 40 kg.
But:
Approximately 100 litre of human correspond to 103 kg.
(100 litre of water corresponds to 100 kg.)

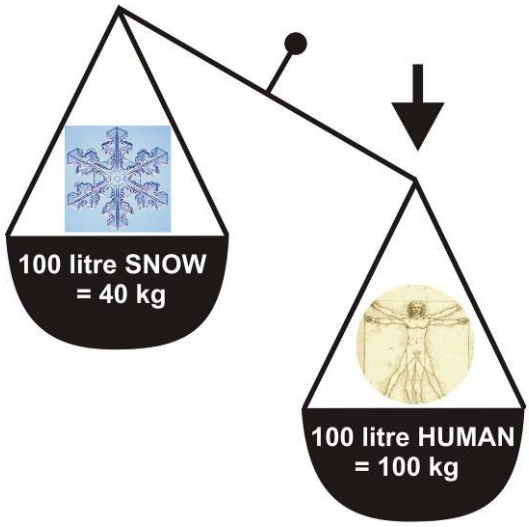


Diagram (12): *Because of higher buoyancy a human body most likely will sink in softer Avalanche debris.*

To get the skier back on top of the snow pack and to keep this skier on top some extra volume is needed. This extra volume

comes from the Airbags filled with specific gas.

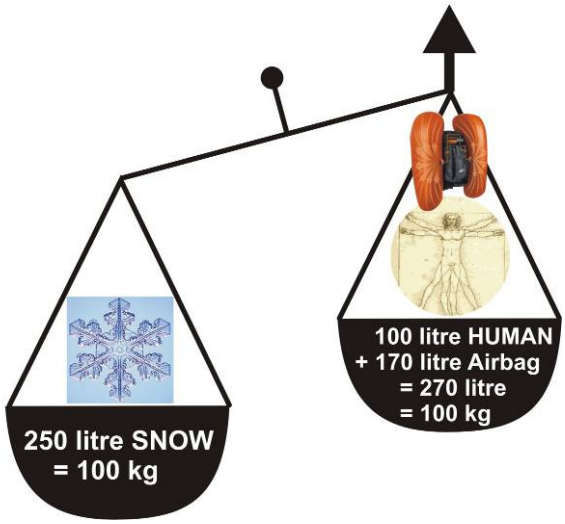


Diagram (13): *A human body plus Airbags most likely will not sink in softer Avalanche snow. The higher the density of Avalanche snow is the less additional Airbag volume is needed.*

Avalanche Transceivers and Avalanche Airbag System

Analyzing the data of accidents shows the complementary functions of Avalanche Transceivers and Avalanche Airbags.
Both systems are needed for successful survival.

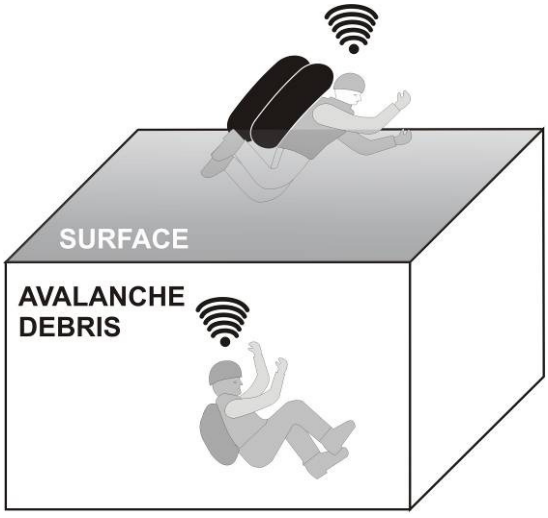


Diagram (14)
Avalanche Transceivers transmit an electromagnetic signal through the debris and allow companion rescue. Beacons cannot hinder a skier to get buried.
The inflated Avalanche Airbag System prevents the burial of the skiers.

Using an Avalanche Airbag does never mean: “Stop using an Avalanche Transceiver!”

Avalanche Transceivers, probes, and shovels are well established rescue gear and still need to be used in combination with the Avalanche Airbag. In most cases the Avalanche Airbag can prevent a burial.

The inflated Avalanche Airbags increase the ratio of the volume of the skier compared to the volume of the granular material of the (Avalanche)-Snow. Chaotic rotating snow crystals creep under larger objects like skiers and these larger objects (i.e. skiers) are lifted onto the surface of the debris. The skier is now safeguarded by the Airbags on top of the debris and will not sink. The airbags prevent a burial, while a skier caught by an Avalanche, transported and being spit onto the surface will sink into the debris again because of his greater density compared to the density of the surrounding snow.

Limitations of Avalanche Airbags

The inflated Airbag System may not keep the skier automatically on top of the debris of the avalanche. It is the motion of the avalanche, the ratio of the additional volume from the Airbags, the principle of separating bigger parts from smaller pieces (= segregation) and the overall shape of the body plus the Airbags which will keep the skier on top.
If the airbag is not inflated, or the avalanche does not transport the skier, the chance of being on top of the debris is the same to a skier using transceiver only. For full function of the Avalanche Airbag the skier needs to pull the trigger handle immediately when realizing the start of the Avalanche. This skier should also try to flee the Avalanche. If escaping is not possible, the skier should remove both poles and skis.
Full function of the Airbag System also needs to be transported by the Avalanche for at least a few meters.
This transportation with the inflated Airbags will ensure the separation of the skier from the smaller particles in the debris and keep the skier on top of the debris. The defined motion of this separation is called “inverse segregation”. As avalanche snow is not a liquid like water, it is not “buoyancy” which gets and keeps us on top of the debris –

it´s the inverse segregation which keeps the person on top of the debris. Dale Atkins (see TAR) called it the “Brazil nut effect”.

Twinbag-System vs. Single-Avalanche-Airbag System

During the first decade of Avalanche Airbag design and production, in the early eighties, a single airbag was mounted on top of a backpack.

There are no statistics available comparing results of Avalanche accidents with single versus double airbags.

Practice shows us each season, that escaping the avalanche is one of the successful strategies surviving such an event (Meiners, et.al). Escaping the avalanche needs full, unrestricted visibility and motion to the left and right. The design of Airbags should consider good visibility and free movement of the head.

In the event of an Avalanche the skier may also be transported over rough terrain or into trees (rocks, branches).

Outcropping rocks and branches might puncture one of the Airbags. Two Airbags can offer a kind of redundancy against this estimated impact.

Two Airbags also provide a more balanced and dynamic motion while being transported from the flowing zone down to the deposition zone. Two Airbags can keep the skier easier in a more horizontal, balanced position.

Triggering the Airbag System

Manual triggering

Airbag triggering is possible by pyrotechnical-pneumatically charged handle or by mechanical Bowden cable, a type of flexible cable to transmit mechanical force.

Remote controlled triggering

The Wireless Activation is an additional opportunity to trigger the Airbag

- of a group endangered on a slope or
- of a single person in this group, when skiing this slope one by one.

The triggering is ignited wireless via a specific frequency.

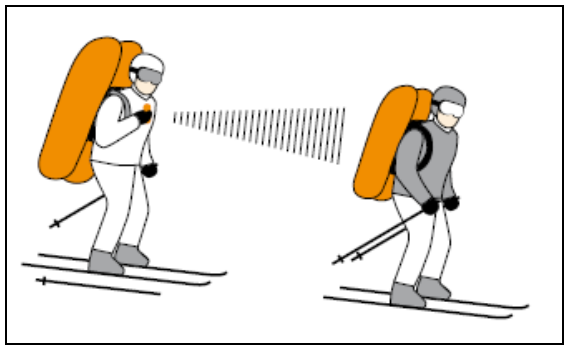


Diagram (15)
Airbag can be inflated by the wireless activation system.

Before starting to ski the group has to initiate a *“triggering community”*. Only members of this group can trigger the Airbags of their specific group. Triggering other groups’ Airbags is excluded!

Temporarily deactivation of the wireless triggering is also provided (Heli-skiing, etc.).

The range of the wireless activation is 300m approximately; each of the group’s wireless system is working as a repeater. This increases the total range significantly.

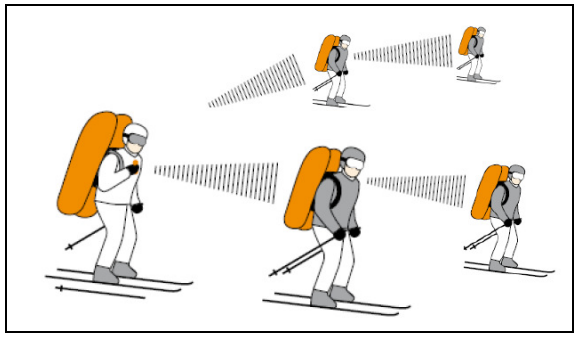


Diagram (16)
Range of the wireless activation systems increases with the repeater-function of each system within the specific group.

It is not always easy to notice the start of a slab avalanche and realizing to be on a slab avalanche might cause a moment of surprise; a kind of “freezing” can occur.

The wireless activation is an additional safety tool in guided and private groups including families skiing with children, for heli-skiing, for snowmobiling groups and for professionals (ski patroller at work).

Avalanche transceivers are not affected by the use of the wireless activation system.

Summary

The convincing rate of success (= 97% survival rate) when using an Airbag System is well proven. It`s now time to add the Airbag System to the personal safety gear.

Avalanche Transceivers, probes and shovels are mandatory when skiing off-piste or while snowmobiling in backcountry areas. Accurate signal analysis and marking is an essential function when it comes to multiple burial scenarios.

The Avalanche Airbag System and modern Avalanche Transceivers in combination are helpful rescue devices without any gadget functions.

LIterature

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