rescue cache

# Testing Transceivers in Multiple-Burial Scenarios

Story by Jürg Schweizer, Manuel Genswein, Fred Jarry, and Dominique Létang

ABSTRACT: Two large-scale field tests at Davos, Switzerland, and on Col du Lautaret, France, focusing on the performance of avalanche rescue transceivers in multiple-burial accidents were conducted during winter 2011/2012. In the Swiss test, beginners searched with low-end transceivers; the French test focused on advanced and professional user groups with top-end transceivers. The complexity of the search scenarios was adapted to the respective user groups. In both tests we measured search time for locating a first, second, and third (and in some scenarios, a fourth) search target. In the Davos test, the novice/average users were unable to locate the third target in about 30% of the cases with four out of five transceivers. This failure was mainly due to the malfunctioning of the marking function. In the second test with the advanced and professional user group, the number of not-found targets was considerable lower as this user group successfully applied backup search strategies. Test results clearly indicate that even using modern transceivers with digital signal processing, the presence of multiple signals during search may still lead to a challenging and problematic situation for the novice rescuer. Backup search strategies are essential for handling complex rescue scenarios and need to be taught.

A view of the test plots in Davos, Switzerland. The 40-50m search fields were machine groomed the previous day to hide any track clues to the transceiver burial locations.

**INTRODUCTION**

Avalanche rescue transceivers (beacons), together with shovels and probes, are the current standard equipment when rescuing persons completely buried by a snow avalanche. As survival chances quickly decrease with time, the rescue effort – including transceiver search, probing, and excavation – needs to be as fast as possible. Although the search time is often substantially shorter than the time it takes to excavate the buried subject, in order to save lives it is vital that the transceiver allow quick and reliable location of the victim. The rescuer, whether relatively inexperienced or professional, has to be able to find the buried subject(s) even under stress and in non-trivial burial situations.

For a couple of years now, the transceivers on the market have included a processor and multi-antenna system that support the rescuer while searching. In single-burial situations (with average burial depth) the search is typically quick and reliable, in particular due to the availability of distance and direction indication. On the other hand, training sessions frequently show that in non-trivial burial situations, when two or more persons are completely buried in close vicinity (i.e., within 220m), the search is more demanding despite the multiple-burial algorithms that support features such as the ability to mask out the signal of an already localized but not yet recovered subject.

Although multiple-burial situations are not the norm, they are not infrequent. Swiss avalanche-accident statistics indicate that a few accidents with two or more buried persons who were not found by visible clues occur every year. In the 10 years from 1998/1999 to 2008/2009 (not including 2006/2007) about 1800 avalanche accidents were reported to the WSL Institute for Snow and Avalanche Research, SLF. In 250 accidents at least one person was completely buried (no visible parts), involving 315 persons. Whereas in most cases only one person was completely buried, 45 accidents with two or more completely buried persons were reported involving in total 110 persons.

In other words, in 18% of the accidents with at least one completely buried person, two or more subjects had to be searched for. Considering the buried persons, the proportion is about 35%, so on average the odds for a buried person are about one-third that at least one other person is completely buried at the same time – with possible dire consequences for survival. In detail, the probabilities for two or more, three or more, and four buried subjects are about 35%, 17%, and 5%, respectively.

In the past, transceiver performance has been regularly tested to monitor transceiver development progress and to compare the different brands of transceivers on the market. However, few tests have been based on quantitative measurements that allow an objective assessment *(e.g., Schweizer, 2000; Schweizer and Krüsi, 2003)*.

The aim of this study was to test the performance of avalanche rescue transceivers in multiple-burial accident situations by the three main user groups: "novice/average" users, "advanced recreational" users, and "professional" users. We conducted two field tests in January and May 2012 in Switzerland and France, respectively. The Swiss test utilized novice subjects, while the French test focused on the advanced and professional user groups which were split into three subcategories: non-commercial mountain leaders, guides, and full-time professional rescuers. Search time for locating the first, second, and third (and in some scenarios, the fourth) search target was measured. Test participants also provided feedback by answering questionnaires.

**Table 1: Characteristics of the two tests**

| | | |
|---|---|---|
| Location | Davos Sertig, Switzerland<br>1860 m a.s.l. | Col du Lautaret, France<br>2200 m a.s.l. |
| Date | 12-13 January 2012 | 12-16 May 2012 |
| User groups | Novice/average | Advanced recreational, certified guides, full-time SAR |
| Number of test participants | 20 (on 1 full day) | 10 per day (on 3 full days), in total: 30 |
| Training | 2 hrs (20 min per brand of beacon by representative of manufacturer) | 3 hrs (45 min per brand by mountain rescue instructors with specific training) |
| Brands and models of beacons tested | ARVA Axis<br>Mammut Element Barryvox<br>Ortovox 3+<br>Pieps DSP Tour<br>Tracker 2 | ARVA Link<br>Mammut Pulse Barryvox<br>Ortovox S1+<br>Pieps DSP |
| Size of square test fields | 40-50 m | 100 m |
| Number of test fields | 10 | 4 |
| Burial depth | 1 m | 1 m, occasionally 2 m |
| Number of search targets per field | 3 | 3, occasionally 4 |
| Search targets | remotely controlled transmitter at exactly 457 kHz simulating a modern beacon with a short-lasting transmit time | remotely controlled transmitters and standard transceivers with different transmit times and frequency deviations |

**METHODS**

In both tests we measured the time for localizing the search targets in a multiple-burial situation. In the test at Davos, Switzerland, on January 12-13, 2012, beginners – a class of inexperienced secondary school students (grade 9, age 16) – tested five low-end transceivers (ARVA Axis, Mammut Element Barryvox, Ortovox 3+, Pieps DSP Tour, Tracker 2), whereas in France on May 12-16, a group of advanced and professional users tested four high-end transceivers (ARVA Link, Mammut Pulse Barryvox, Ortovox S1+, Pieps DSP) *(see Table 1)*.

In the test at Davos we used radio-controlled search targets that simulated a generic, modern transceiver. The targets had a short-lasting transmit time of approx 100ms followed by a randomly chosen pause of approx 950-1050ms in order to minimize longer lasting signal overlaps. All search targets were transmitting a 457 kHz signal with very little to no frequency deviation and no continuous carrier. In France, only one test field was equipped with remote-controlled search targets; the remaining fields were set up with standard transceivers in transmit mode. Additional search information such as W-Link information, including MAC addresses and 457 kHz time stamps, were purposely disabled to give equal chance to devices outside of the ARVA/Barryvox W-Link platform.

Antenna orientation varied *(see Figures 1 and 2)*. In Davos all antenna were oriented parallel (not inclined) to the snow surface, resulting in relatively easy scenarios, whereas for the advanced and professional users groups at Col du Lautaret, the antenna orientations were more variable, and consequently the scenarios were more complex and demanding. Search targets were buried in a depth of 1m below a wooden plate of 50cm × 70cm. This burial depth corresponds to the median burial depth in human-triggered avalanche accidents *(Harvey and Zweifel, 2008)*. At Col du Lautaret, to add some challenges in the fine search phase, some objects were buried between 2 and 2.3m.

The search targets were equipped with probe detectors that allowed us to measure search time to the point when the rescuer hit the wooden plate with the probe pole. We recorded search times for localizing (probe hit) the first, second, and third search target (and at Col du Lautaret, occasionally the fourth target). The participants started in the middle of one side of the test field with the transceiver in transmit mode, so

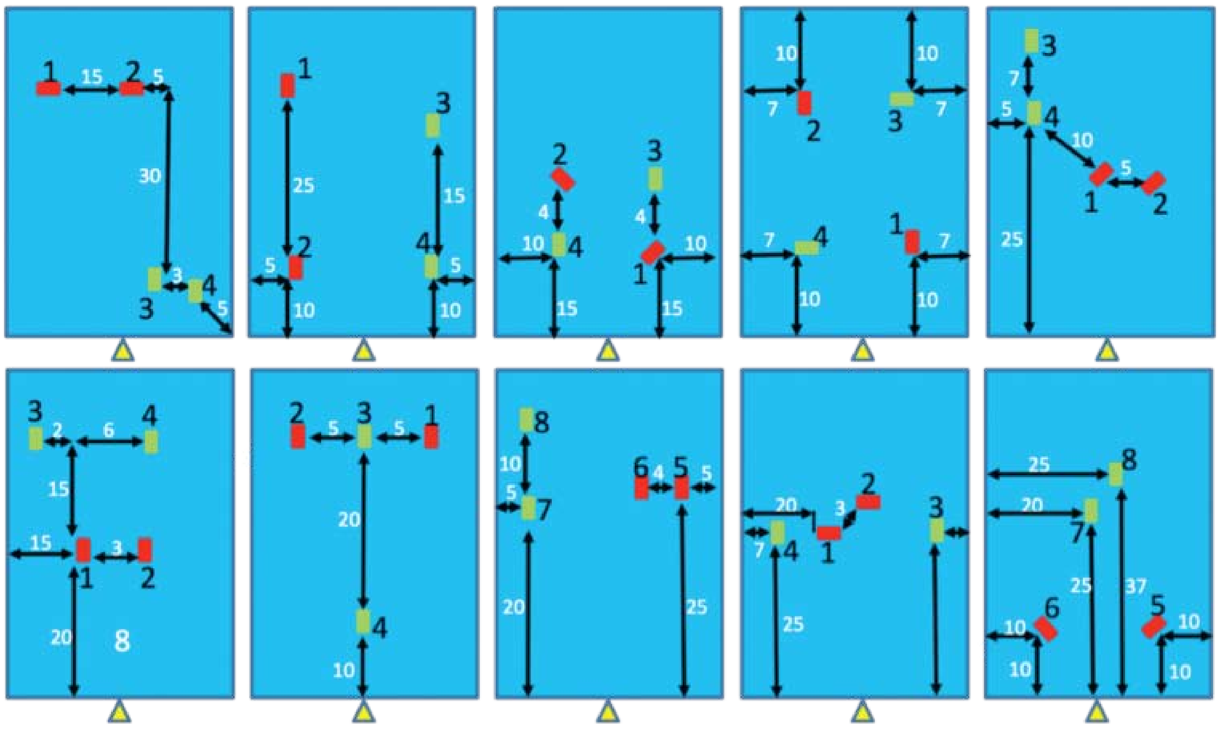

**Figure 1: Test search scenarios at Davos**

This figure illustrates the location of four search targets buried in each field. The transmitters in green were always turned on. The transmitters in red only had one of the two turned on at the same time. White numbers indicate distance in meters between targets or to the test field border. Black numbers are search target identifiers. Triangles mark the starting points.

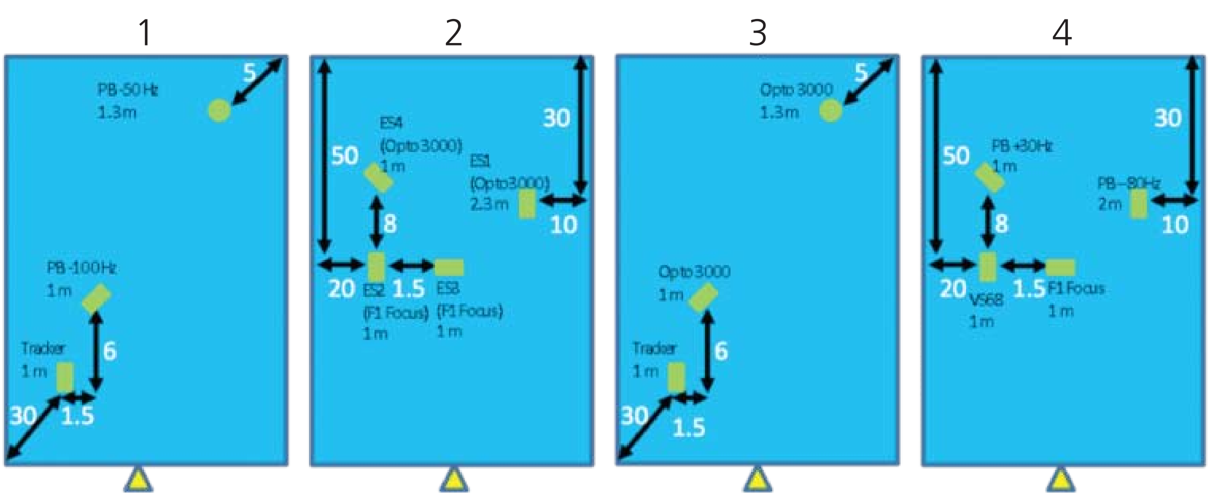


**Figure 2: Test search scenarios at Col du Lautaret**

Same presentation as in Figure 1, above. In these scenarios, all transmitters were turned on at all times. The circular transmitter symbol indicates vertical antenna orientation.

switching into search mode was part of the measured search time. Times were recorded by a field assistant who rotated clockwise from one field to the other, whereas test participants rotated counter-clockwise in order to prevent any bias from particularly positive or negative interaction between participant and field assistant.

The sides of the approximately square search fields were 40-50m at Davos and about 100m on Col du Lautaret. The average deposit size of human-triggered avalanches is about 50m × 70m, but in those cases where persons are completely buried, the average deposit size is about twice as large (about 80m × 100m). Hence, the test fields in Davos were relatively small so that there was hardly any signal search, however testing search performance in multiple-burial situations made this drawback almost irrelevant. The relatively small test fields slightly favored transceivers with a rather small range, but only when searching for the first target.

On the other hand, in the test at Col du Lautaret the search fields were larger than the median deposit size of human-triggered avalanches with completely buried persons, which is about 8400m2 *(Genswein et al., 2009)*. Test fields at Davos were prepared with a grooming machine and boot-packed on Col du Lautaret on the previous day so that conditions for moving around on the test fields were always similar, and tracks did not reveal the burial locations.

In all test fields at Davos, four search targets were buried. Two of them were always turned on *(Figure 1, in green)*, whereas the other two were activated alternatively by the radio control unit *(Figure 1, in red)*. This allowed two different burial scenarios of similar complexity.

On Col du Lautaret, the four test fields were split in two pairs in which the search scenarios had almost the same layout of buried objects as the Davos tests, including transmitter orientations and transmit patterns *(see Figure 2)*. This setup allowed us to measure the influence of transmit frequency deviation as well as the influence of radio-controlled test equipment such as remotely controlled search targets.

On Col du Lautaret, one set of two test fields *(numbers 1 and 3 in Figure 2)* was a simple multiple-burial situation with three search targets activated at one time – very similar to the ones used in the test at Davos. This included the transmit pattern of the transmitter with short transmit times, randomization in period length, and no continuous carriers. The only difference between the two fields was the 457 kHz transmit frequency deviation in test field number 1. Two out of the three transmitters had a transmit frequency deviation: one transmitter was at 456'950 Hz, therefore with 50 Hz still within the allowed bandwidth of ±80 Hz as defined by the ETS 300718 regulatory standard for avalanche rescue transceivers. The other transmitter was at 456'900 Hz with a deviation of -100 Hz; this transmitter was outside of the allowed transmit frequency of the current version of ETS 300718, but just at the lowest limit of the tolerance field of the previous version of the standard which had a less-restrictive ±100 Hz tolerance field. As frequency deviation toward lower frequencies is more common than deviation toward higher frequencies *(Genswein et al., 2009)*, three out of four search targets with frequency deviation were below the nominal frequency, and only one, in test field number 4, was with a transmit frequency of 457'030 Hz above the nominal frequency (+30 Hz).

The other set of test fields *(numbers 2 and 4 in Figure 2)* featured a demanding multiple-burial situation with four search targets activated at one time. Two transmitters in close proximity had long-lasting transmit times and some continuous carriers, leading to a challenging situation with frequent signal overlap – an ideal setup to test how the transceiver is able to support the search with its multiple-burial algorithms, as well as allowing the rescuer to verify the feasibility of the implemented algorithms

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# TRANSCEIVER TESTS

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– and to apply alternative search tactical systems, if required.

Training of the test participants in Davos for the novice users consisted of five device-specific workshops of 20 minutes each. Due to the low level of training at the Davos test, most of the teaching was strictly device-related, and therefore the workshops were taught by a representative appointed by the transceiver manufacturer.

The training at Col du Lautaret took three hours for the four devices, so about 45 minutes for each workshop. The pre-existing level of knowledge and training for these more-advanced test participants was much higher, but the scenarios were more challenging, so the test participants needed to be prepared to recognize when the device's regular search mode became inefficient or unreliable (i.e., by scan functions or analog sound check) and what backup search strategies should be applied in such situations (i.e., micro-search strips or micro-box). The transceiver manufacturers' user manuals were consulted in order to teach in compliance with their official recommendations. However, in cases where the user manual did not specify any strategy to solve the respective search problem, a generic strategy was taught and adapted to the capabilities of the individual device. The formal course curriculums for each device are available on request and will be published elsewhere.

## RESULTS

In the test at Davos with novices, the first target was found on average within about two minutes with all the different brands *(see Table 2)*. When localizing the second target, the first differences showed up. Search times were longer with the ARVA Axis and the Pieps DSP Tour than with the other three beacons. In addition, in five out of 40 cases the second target could not be found within the time limit – which was initially 10 minutes, then 12 minutes after the second round. The number of targets not found increased when searching for the third target.

With all brands of transceivers, at least one search target (Mammut Element Barryvox) and up to 23 search targets (Pieps DSP Tour) were not found. The difference in performance – in terms of search time as well as not-found targets – was significant, and clearly shows that considerable differences exist between the various brands of transceivers.

Overall, the novices searched best with the Mammut Element Barryvox; they had most problems with the Pieps DSP Tour. The main problems with the ARVA Axis and the Pieps DSP Tour were the malfunctioning of the marking feature and general problems with locating the second or third target.

In the test on Col du Lautaret the times for locating the first target were only about one minute longer than at Davos *(see Table 3 & 4)*. Again, the first target was located with all beacons within about three minutes. Even for the second and third target, times were fairly similar between brands. Only in the more challenging scenarios (numbers 2 and 4), differences became larger for locating the fourth target, but overall the results were not statistically significant. The number of not-found targets was considerably smaller than in Davos, between one (Pulse Barryvox) and four (Pieps DSP) search targets not found.

The time limit for the more complex scenarios on Col du Lautaret was 25 minutes. The experienced or professional users were able to locate the targets even if, for example, the built-in marking function did not work. Considering search times, the Mammut model (Pulse Barryvox) performed best overall. The Pieps DSP ranked second, followed by the ARVA Link and the Ortovox S1+. According to the comments, the test participants mentioned problems with the marking function most often for the Pieps DSP.

On the field with transmitters with frequency deviations, the search was not slower in general. Differences were relatively small, and deviations were positive as well as negative. The most distinct difference was found with the Pieps DSP. Locating the fourth target in scenario number 4 took 18 minutes versus about 14 minutes in scenario number 2 (with no frequency deviation).

Considering the three subcategories of users, the search performance for the non-commercial mountain leaders and the certified guides was similar. However, the full-time professional mountain rescuers found the buried subjects about 20% faster on average than the other two groups.

### Table 2: Field Test Results at Davos

| | ARVA Axis | Element Barryvox | Ortovox | Pieps DSP Tour | Tracker 2 |
|---|---|---|---|---|---|
| Number of test results for first, second, and third target | 40 / 40 / 40 | 40 / 40 / 36 | 40 / 40 / 40 | 40 / 40 / 40 | 40 / 40 / 36 |
| Time* for localizing the first target (min:sec) | 2:00 | 1:45 | 2:00 | 2:00 | 1:30 |
| Time* for localizing the second target (min:sec) | 5:45 | 3:45 | 4:30 | 6:00 | 4:00 |
| Time* for localizing the third target (min:sec) | 10:00 | 6:00 | 6:15 | 10:00 | 7:00 |
| Number of cases where the first, second, or third target was not found within the time limit | 0 / 5 / 18 | 0 / 0 / 1 | 0 / 1 / 12 | 0 / 5 / 23 | 2 / 2 / 11 |

### Table 3: Field Test Results at Col de Lautaret

| | ARVA Link | Pulse Barryvox | Ortovox S1+ | Pieps DSP |
|---|---|---|---|---|
| Number of test results for first, second, third, and fourth target | 31 / 31 / 31 / 16 | 28 / 28 / 28 / 15 | 33 / 33 / 33 / 14 | 30 / 30 / 30 / 15 |
| Time* for localizing the first target (min:sec) | 3:15 | 3:00 | 3:30 | 3:00 |
| Time* for localizing the second target (min:sec) | 5:30 | 5:15 | 6:15 | 5:15 |
| Time* for localizing the third target (min:sec) | 10:30 | 8:45 | 9:45 | 9:30 |
| Time* for localizing the fourth target (min:sec) | 14:00 | 12:15 | 15:30 | 17:30 |
| Number of cases where the first, second, or third target was not found within the time limit | 0 / 0 / 1 / 2 | 0 / 0 / 1 / 0 | 0 / 1 / 2 / 0 | 0 / 0 / 3 / 1 |

*median values, rounded to quarter minutes


Advanced and professional users search at the Col du Lautaret. *Photo by Manuel Genswein*

## DISCUSSION

Novice and average users depend more than any other user group upon the high reliability, performance, user friendliness and error tolerance of their transceiver. These users' limited training along with the limited functionality of low-cost devices does not allow detecting when the device is not capable of fulfilling the task of finding all buried subjects, nor are the devices or users able to apply the required backup strategies.

On the other hand, the experienced and professional users were sufficiently trained to recognize the problems and apply more complex but reliable backup search strategies, once the scenarios exceed the capabilities of the digital search modes. Only thanks to the advanced search skills of this user group and the extended capabilities of the top-level devices, the percentage of buried subjects not found was considerably lower in the test on Col du Lautaret – in particular, for the brands that did not perform well in the test at Davos.

## CONCLUSIONS

Two large field tests were conducted focusing on search time in multiple-burial situations. In the test at Davos, novice to average users with limited training – the group that probably accounts for the vast majority of all companion rescuers – searched with five low-level transceivers. In the test on Col de Lautaret, experienced and professional users searched with four top-level transceivers. With all transceivers, the novices had almost no problem locating the first target within about two minutes on average. Search times significantly differed between the various brands. Most importantly, with four out five beacons the inexperienced users were unable to locate the third target in about one third of the cases (on average).

Finding the third or fourth target was less of a problem for the experienced and professional user groups in the test on Col du Lautaret. Though differences existed in search times, the differences overall were statistically not significant. This user group was capable of handling almost any situation, independent of the type of transceiver, because they knew backup search strategies.

The higher the training level of the rescuer, the better he is able to detect deficiencies of a device and apply a tactical search workaround.

Our tests clearly show that even the most advanced digital search modes are still not 100% reliable. Therefore, backup search strategies are essential for handling complex rescue scenarios, and these need to be taught.

Moreover, for accident prevention, our findings confirm that exposure of several persons as well as several parties on the same slope should be avoided whenever possible as these factors considerably increase the risk of a fatal outcome in case of an accident.

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