Transceiver Performance When Searching for Multiple Burials

Jürg Schweizer
WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland

Manuel Genswein
Genswein, Meilen, Switzerland

Fred Jarry, Dominique Létang
ANENA, Grenoble, France

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 IN WINTER 2011-12.

WHEREAS in the Swiss test beginners searched with low-end transceivers, the French test focused on the advanced and professional user groups who used 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 the first, second and third (and in some scenarios the fourth) search target.

In the test at Davos, with four out five transceivers the novice/average users were unable to locate the third target in about 30% of the cases. 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 considerably lower, as this user group successfully applied backup search strategies.

Test results clearly indicate that even with modern transceivers with digital signal processing, the presence of multiple signals during search may still lead to a challenging and problematic situation for the rescuer. Backup search strategies are essential for handling complex rescue scenarios and need to be taught.

1. INTRODUCTION

Avalanche rescue transceivers (or beacons) together with shovel and probe are the standard equipment for snow avalanche rescue. As the survival chances quickly decrease with time, the rescue—including transceiver search, probing and excavation—needs to be as fast as possible. Although the search time is often substantially shorter than the time spent excavating the buried subject, it is vital that the transceiver allows the victim to be quickly and reliably rescued in order to save lives. 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 several years, the transceivers on the market include a processor and multi-antenna system that supports 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 2-20m), 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.

The Swiss avalanche accidents statistics indicate that every year, a few accidents with two or more buried persons occur who were not found by visible clues. In the 10 years from 1998-99 to 2008-09 (not including 2006-07), about 1800 avalanche accidents were reported to the SLF. In 250 accidents, at least one person was completely buried (no visible parts) for a total of 315 involved people. Whereas in most cases only one person was completely buried, 45 accidents with two or more completely buried persons were reported, involving a total of 110 persons. In other words, in 18% of the accidents with at least one completely buried person there were two or more subjects that had to be searched for.

Considering just buried persons, the proportion is about 35%. That is, on average the odds are about one third that at the same time at least one other person is completely buried, with possibly severe 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 the progress in development and to compare different brands on the market. However, only a few tests were 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 users groups: 'novice/average' user, 'advanced recreational' user and 'professional' user. We conducted two field tests in January and May, 2012 in Switzerland and France, respectively. Whereas in the Swiss test beginners were searching, the French test focused on the advanced and professional user groups that split up in three subcategories: non-commercial mountain leaders, guides and full-time professional rescuers. Search time for locating the first, second, and third (in some scenarios the fourth) search target was measured. In addition, the test participants provided feedback by answering questionnaires.

2. METHODS

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

In Davos we used radio-controlled search targets that simulated a generic, modern transceiver. The targets had a short lasting transmit time of approximately 100ms followed by a randomly chosen pause of approximately 950 to 1050ms in order to minimize longer lasting signal overlaps. All search targets where 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 (Figures 1 and 2). In Davos, all antenna were oriented parallel (not inclined) to the snow surface, resulting in relatively easy scenarios,. For the advanced and professional users groups at Col du Lautaret, the antenna orientations were more variable and the scenarios

FIG. 1: SEARCH SCENARIOS IN THE TEST AT DAVOS. IN EACH FIELD FOUR SEARCH TARGETS ARE BURIED. TRANSMITTERS IN WHITE COLOR ARE ALWAYS TURNED ON, OF THE TRANSMITTERS IN GREY COLOR ONLY ONE OF THE TWO IS TURNED ON AT THE SAME TIME. WHITE NUMBERS INDICATE DISTANCE BETWEEN TARGETS OR TO THE BOARDER OF THE TEST FIELD IN METERS. BLACK NUMBER ARE SEARCH TARGET IDENTIFIERS. TRIANGLES MARK THE STARTING POINT.

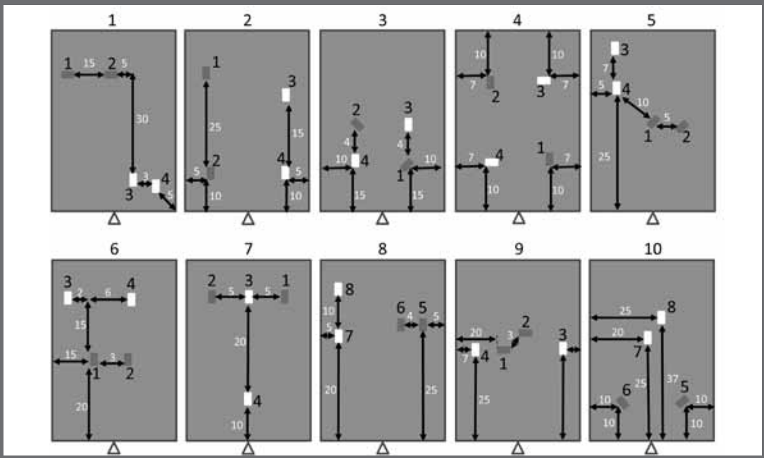

FIG. 2: SEARCH SCENARIOS IN THE TEST ON COL DU LAUTARET. SAME PRESENTATION AS IN FIG.1. ALL TRANSMITTERS ARE TURNED ON AT ALL TIMES. THE CIRCULAR TRANSMITTER SYMBOL INDICATES VERTICAL ANTENNA ORIENTATION.

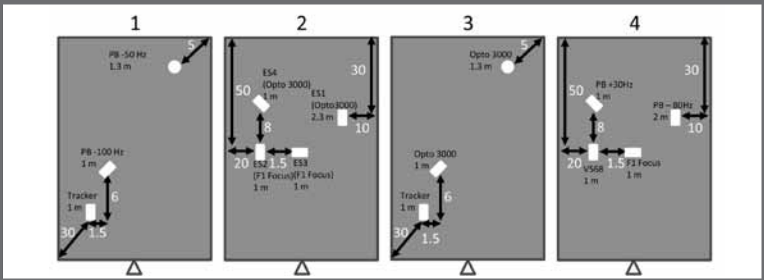

TABLE 1: CHARACTERISTICS OF THE TWO TESTS		
LOCATION	Davos Sertig, Switzerland 1860m ASL	Col du Lautaret, France 2200m ASL
DATE	January 12-13 2012	May 12-16 2012
USER GROUPS	Novice/average	Advanced recreational, certified guides, full-time SAR
NUMBER OF TEST PARTICIPANTS	20 (on 1 full day)	10 per day (on 3 full days), 30 in total
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 Mammut Element Barryvox Ortovox 3+ Pieps DSP Tour Tracker 2	ARVA Link Mammut Pulse Barryvox Ortovox S1+ Pieps DSP
SIZE OF SQUARE TEST FIELDS	40-50m	100m
NUMBER OF TEST FIELDS	10	4
BURIAL DEPTH	1m	1m, occasionally 4
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


MANUEL GENSWEIN

consequently more complex and demanding. Search targets were buried in a depth of 1m (see exceptions below) 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). To add some challenges to the fine search phase at Col du Lautaret, some objects were buried between 2 and 2.3m.

The search targets were equipped with probe detectors measured search time to the point when the rescuer hit the wooden plate with the probe pole. We recorded search times for localizing (with a probe hit) the first, second and third search target (and occasionally the fourth target at Col du Lautaret). The participants started in the middle of one side of the test field with the transceiver in transmit mode. 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; test participants rotated counter-clockwise in order to prevent any bias from particularly positive or negative interaction between participant and field assistant.

The search fields were approximately square: the sides were 40-50m at Davos and about 100m on Col du Lautaret. Whereas the average deposit size of human-triggered avalanches is about 50m × 70m, it is about twice this size in those cases where persons were completely buried (about 80m × 100m). Hence, the test fields in Davos were relatively small so that there was hardly any signal search. However, when testing the performance for multiple burial situations, this drawback was 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 complete buried persons, which is about 8400m^2 (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

TABLE 2: RESULTS OF FIELD TEST AT DAVOS				
	ARVA Axis	Element Barryvox	Ortovox 3+	Pieps DSP Tour
NUMBER OF TEST RESULTS FOR FIRST, SECOND AND THIRD TARGET	40 / 40 / 40	40 / 40 / 36	40 / 40 / 40	40 / 40 / 40
TIME* FOR LOCALIZING THE FIRST TARGET (MIN:SEC)	2:00	1:45	2:00	2:00
TIME* FOR LOCALIZING THE SECOND TARGET (MIN:SEC)	5:45	3:45	4:30	6:00
TIME* FOR LOCALIZING THE THIRD TARGET (MIN:SEC)	10:00	6:00	6:15	10:00
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

TABLE 3: RESULTS OF FIELD TEST ON COL DU LAUTARET				
	ARVA Link	Pulse Barryvox	Ortovox S1+	Pieps DSP
1. 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

around on the test fields were always similar and tracks did not reveal burial locations.

In all test fields at Davos, four search targets were buried. Two of them were always turned on, whereas the other two were activated alternatively by the radio control unit. 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 scenario was almost the same for the layout of the buried objects including its transmitter orientation and transmit pattern. This setup allowed researchers to measure the influence of transmit frequency deviation as well as of radio-controlled test equipment such as remotely controlled search targets.

One set of two test fields (no. 1 and 3 in Fig. 2) had 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 no continuous carriers. The only difference between the two fields was the 457 kHz transmit frequency deviation in test field no. 1. Two out of the three transmitters had a transmit frequency deviation: one transmitter was at 456'950 Hz and therefore with a deviation of 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 was less restrictive with a ±100 Hz tolerance field. As frequency deviation towards lower frequencies is more common than deviation towards 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 no. 4, was with a transmit frequency of 457'030 Hz above the nominal frequency (+30 Hz).

The other set of test fields (no. 2 and 4 in Fig. 2) was 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, and to apply alternative search tactical systems, if required.

Training the novice user test participants in Davos consisted of five twenty-minute, device-specific workshops. Due to the low level of training at the Davos test, most of the teaching was strictly device related, and therefore a representative appointed by the transceiver manufacturers taught the workshops. The training at Col du Lautaret took three hours for the four devices: about 45 minutes per workshop. The pre-existing level of knowledge and the level of training were much higher but the scenarios were more challenging; the test participants needed to be prepared to recognize when the device's regular search mode became inefficient or unreliable (e.g. by scan functions or analog sound check), and what backup search strategies should be applied in such situations (e.g. micro-search-strips or micro-box). The official manufacturer's user manuals were consulted to teach in compliance with the official manufacturer's 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.

3. RESULTS

In the test at Davos with novices, the first target was found within about two minutes with all the different brands on average (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: initially 10 minutes and then 12 minutes after the second. The number of targets that were not found increased when searching for the third target. With all brands of transceivers, at least one (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 between the various brands of transceivers exist. 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 in 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 (Table 3). Again within about three minutes the first target was located with all beacons. Even for the second and third target times were fairly similar between brands. Only in the more challenging scenarios (no. 2 and 4) did differences become larger for locating the fourth target, but overall were not statistically significant. The number of not-found targets was considerably smaller than in Davos, between one (Pulse Barryvox) and four (Pieps DSP). The limit for the more complex scenarios on Col du Lautaret was 25 min. 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) overall performed best, 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 no. 4 took 18 minutes vs. about 14 minutes in scenario no. 2 (with no frequency deviation).

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

4. DISCUSSION

Novice and average users depend more than any other user group on a high reliability, performance, user friendliness and error tolerance of their transceiver. Their limited training and the limited functionality of low-cost devices do neither allow detecting when the device is not capable to fulfill the task of finding all buried subjects nor would the devices or users be 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 which were not found was considerably lowered in the test on Col du Lautaret—in particular for the brands which did not well in the test at Davos.

5. CONCLUSIONS

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

Not finding the third or fourth target was less a problem with the experienced and professional user group in the test on Col du Lautaret. Though differences existed in search times, those were overall statistically not significant. This user group was capable of handling almost any situation independent of the type of transceiver since 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 search tactical workaround.

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

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

ACKNOWLEDGEMENTS

The authors would like to thank the many participants and helpers of the test who have given in their time, in particular Sébastien Gerard, Yann Paitreaud and Cyril Valantin. We are grateful to different PGHM and CRS posts that have sent their rescuers as participants. Without the help of all the volunteers this project would not have been possible and the authors are very thankful for their efforts and initiative.

REFERENCES

Genswein, M., Reiweger, I. and Schweizer, J., 2009. Survival chance optimized search strip width in avalanche rescue. *Cold Regions Science and Technology*, 59(2-3): 259-266.

Harvey, S. and Zweifel, B., 2008. New trends of recreational avalanche accidents in Switzerland. In: C. Campbell, S. Conger and P. Haegeli (Editors), Proceedings ISSW 2008, International Snow Science Workshop, Whistler, Canada, 21-27 September 2008, pp. 900-906.

Schweizer, J., 2000. The European avalanche beacon test "LVS-98". *American Alpine News*, 9(228): 28-32.

Schweizer, J. and Krüsi, G., 2003. Testing the performance of avalanche transceivers. *Cold Regions Science and Technology*, 37(3): 427-436.