

Simple and Reliable Methodology to Compare Various Avalanche Beacons Taking into Account the Useful Range, Multiple Burial, and the Strength of the Third Antenna

Schreilechner, Marcellus¹ Eck, Markus²; Schober, Michael
¹Joanneum Research Forschungsgesellschaft mbH, Leoben, Austria
²PIEPS GmbH, Parkring 4, Lebring, Austria

ABSTRACT In the spring of 2010, all commercially available avalanche beacons were compared in terms of their useful range, the quality of the indication of direction, the reliability of the mark function, and the strength of the third antenna with a newly devised chessboard experiment. The chessboard experiment is a field study where an area of 50 m x 50 m is subdivided into sections of 5 m x 5 m in order to simply record the search path. In previous studies presented at the ISSW (Eck et al., 2008; Schreilechner et al., 2009), a differential GPS (DGPS) was used; however, this methodology requires sufficient knowledge and experience of a DGPS. With the new methodology of the chessboard experiment, all common users and user groups can reliably check and compare different commercially available avalanche beacons themselves. This new methodology can also be used as a basic knowledge tool at different mountain courses and to serve as a test for publications in order to compare avalanche beacons. The useful range of different avalanche beacons was tested for various coupling positions from the transmitter to the receiver. The qualities of the direction indicators were verified by following the displays towards the transmitter. The reliability of the mark function was also tested with multiple burial scenarios. After marking the first transmitter, the accuracy of finding the second transmitter was tested and verified. The range of the third antenna was checked by positioning the transmitter vertically on a fixed 5 m long wooden pole and then recording the signal maxima of the different receivers.

1 INTRODUCTION

It is often a logistical and technical challenge for group leaders (mountain and ski guides, instructors, etc.) to organize and conduct fieldwork to compare avalanche beacons. First, one must choose and prepare a suitable test site and then the different beacons must be compared in a reproducible and fair manner. It is important to compare the beacon's technical capabilities, their relevance for in-field application, and their usability. Since the usability is not easy to compare, this study was limited to the testing of the technical performance and in-field application.

Genswein & Schweizer (2008), Schweizer (2007), Semmel (2007), Schweizer & Krüsi (2003), and Meier (2001) give good overviews of different methods to determine the useful ranges of beacons and to calculate the search strip widths.

In previous field studies (Eck, et al., 2008; Schreilechner, et al., 2009), currently commercially available multi-antenna beacons were evaluated. (see Figure 1).

**Corresponding author address:* Marcellus Schreilechner, Joanneum Research Forschungsgesellschaft mbH, Institute of Resources, Leoben, Austria, tel: +43 316 876 2245; email: marcellus.schreilechner@joanneum.at

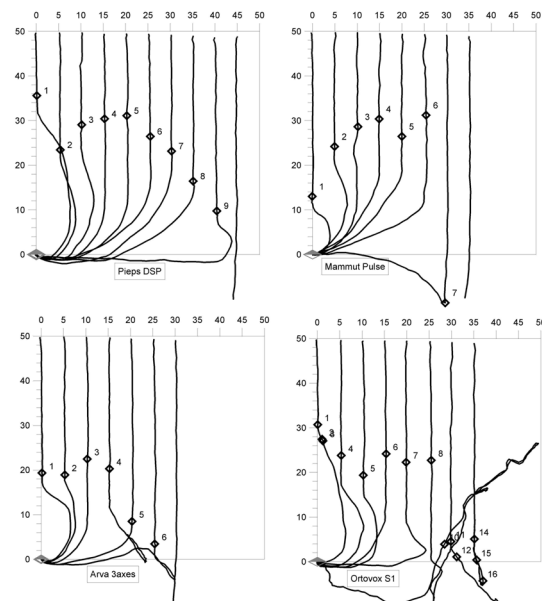


Figure 1: Search paths of four different 3-antenna beacons in "bad coupling position". The plotted points are the positions of the first received signal. The range of each transceiver (starting from the top left and going clockwise) is 40 m, 30 m, and 25 m. (modified after Schreilechner et al., 2009).

These extensive field studies have shown that the reception characteristics of individual devices can vary significantly. This variation is due to the different interactions of the individual receiving antennae in multiple antenna beacons.

2 BACKGROUND

In order to compare the technical performance of various beacons, it is important to consider the following basic knowledge:

First, the various coupling positions (see Figure 2) of a transmitter to a receiver are important for comparing ranges. A “good coupling position” is when the antenna of the transmitting device is parallel/coaxial to the most sensitive antenna of the receiving device. Most multiple antennae beacons contain one antenna with a significantly better receiving characteristic. The elliptical receiving characteristic of avalanche beacons is the reason why some manufacturers recommend the user to swing, turn or rotate the beacon in order to receive an initial signal. However, these recommendations are weakly defined and therefore, are rarely applied correctly by the users (e.g. movement too fast).

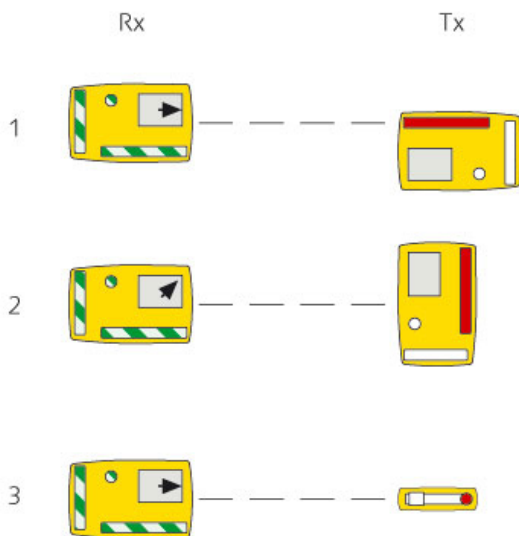


Figure 2: Various coupling positions of transmitters and receivers. (1) Good (2) bad and (3) worst coupling position. Rx = Receiver – with three active antennae, Tx = transmitter – has only one active antenna.

“Bad coupling position” is when the transmitting antenna is perpendicular to the most sensitive receiving antenna.

The “worst coupling position” is when the transmitting antenna is in a vertical position, while the receiving antenna is horizontal.

In practice, the orientation of the transmitting antenna is unknown.

During a search, the accuracy of the displayed direction and distance on the receiving device is important.

A reliable direction indicator on the Rx-beacon is only possible if both the x and y antennae are receiving data. For a beacon with a 360° direction display, the direction indicator should be followed without considering the displayed distance. However, for devices with a limited angle indicator (mostly 120° i.e. $\pm 60^\circ$), the distance display must be taken into account.

Second, in the case of a multiple burial scenario, many commercially available beacons can mark and display the first beacon found and then suppress its signal in the Tx beacon. This allows for other signals to be detected.

However, these types of beacons have different speeds and stabilities and will affect an ongoing search for further victims. In essence, there are two procedures for such beacons:

- 1) Field studies show that an accurate mark of the first beacons reduces the receiving range of second beacons.
- 2) Not focusing on the first beacon, which needs to be marked, the user continues with maximum range for further signals.

Third, as of 2003, the problem of multiple maxima in depth burials is considered technically solved due to the introduction of the third antenna (first commercially available 3-antenna beacon with marking capabilities). Even for extreme depths of the transmitter (> 1 m), only one signal maximum is displayed on the surface so that a systematic rescue can be started with the help of avalanche probes and shovels. Figure 3 (2, red curve) shows that the effect of multiple maxima at the snow surface is most significant when the transmitting antenna is in a vertical position.

This signal maximum is circular at the snow surface. When a rescuer works with a single or 2-antenna device, he acquires the risk of probing and digging in the wrong position. This is also the case when the range of the third antenna is not large enough. The effect of multiple maxima also occurs if the transmitter is in a horizontal position (Figure 3, 1). For shallow burial depths, these so-called side maxima are mostly low, so that the receiver cannot display them. In the case of an ava-

lanche burial, a transmitter will usually have an arbitrary position (Figure 3, 3).

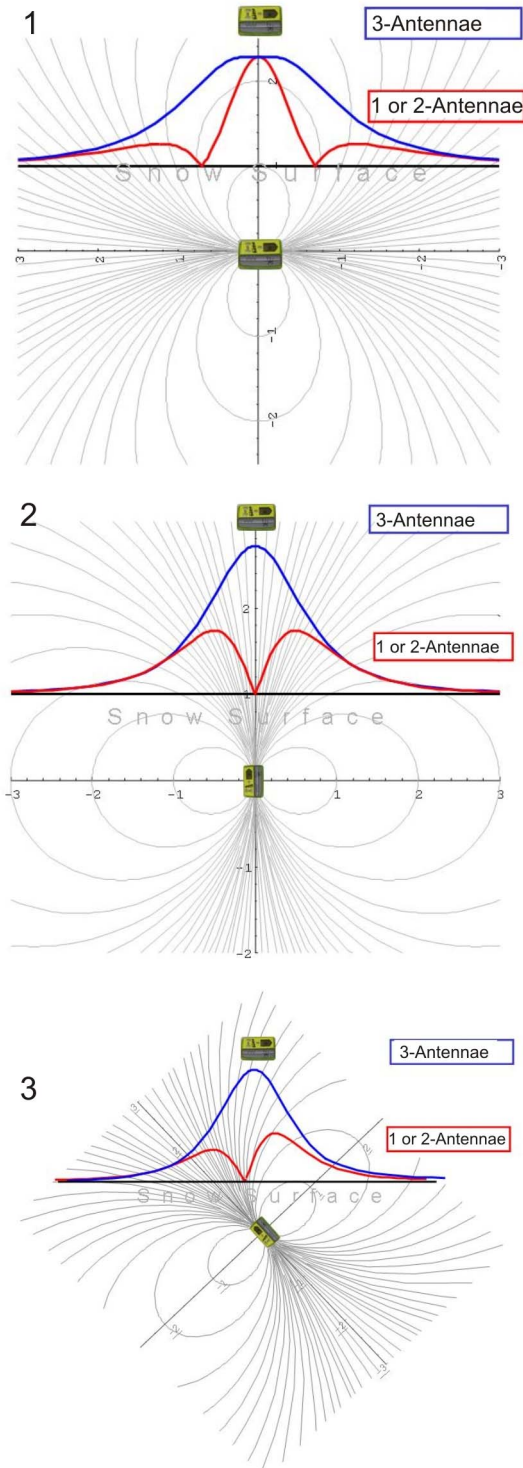


Figure 3: Problem of multiple maxima (red curves) at deep burials if the receiver is a single or 2-antenna beacon only. This problem has the highest impact for a vertical antenna position (2).

The deeper the victim is buried, the further the distance of the individual signal and the more important it is that an adequate function of the third antenna is used.

A final indirect function of beacons is the automated switching from search mode to transmitting mode. This can be induced by a timer or a motion sensor. This "Search to Send" function is used to automatically switch to the transmitting mode during rescues in cases of secondary avalanches. However, it is assumed that the beacon is not safely secured to the body of the rescuer so that a secondary avalanche can separate the beacon from the person. This transceiver would send misleading signals to search teams. Therefore, the authors recommend to generally disable this function on the beacon.

3 FIELD STUDY AND METHODOLOGY

3.1 Chessboard test – range check

In a test site, a square 50 m by 50 m snowfield is defined by poles. To setup a right angle in open terrain frequently imposes problems to testers. The following instructions are intended to aid in this process. According to the Pythagorean theorem, the aspect ratios in a right-angled triangle can be 3:4:5 (Pythagorean Triple).

Because of $3+4+5 = 12$, one can divide a rope into six equal segments. From one side of the rope, measure two sixths ($4/12$) of the rope and from the other side measure one and a half sixths ($3/12$) of the total rope length. These two pieces of the rope form the short sides of a triangle (catheti), the remaining rope forms the long side (hypotenuse). Using the three parts of the rope, a right-angled triangle can be made. A right angle of arbitrary size can be created from this basic shape by aligning longer ropes with the legs of the right triangle. To finally set up the square test field (chess board), this process is repeated on a second corner point.

The field is now divided into sections with a width of 5 m. These sections are marked on the two field sides with various objects (color flags or similar objects – skis, ski poles or backpacks). The imaginary lines connecting the objects (A to K, see Figure 4) are marked by footprints in the snow.

At one corner (A, 0), a beacon is positioned in a good coupling position (see background). Starting from the opposite corner, a beacon is carried along the marked line – e.g. KK – until the first signal is detected. The direction as well as the distance of this signal must be displayed clearly and stably. Now the user follows the indicator to the transmit-

ter. The positions where lines are crossed while moving towards the sender are marked (gloves, flags or other items).

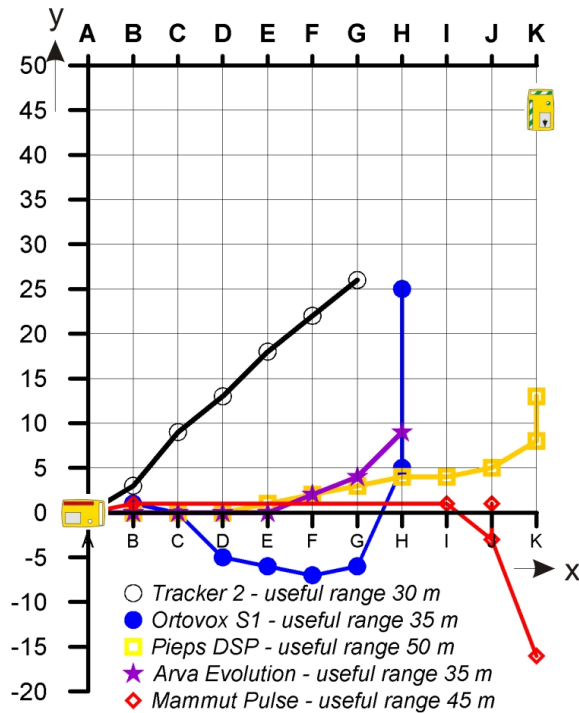


Figure 4: Chessboard test. Setup of a field test to determine the range and quality of the direction indicator of different beacons. The transmitter is located at the origin (A, 0). The approach was made with a bad coupling position. The initial signal and the search path are marked with various symbols.

These marks now describe the search path of the field line method. The position of each marked point is defined in the coordinate system and can be recorded. The x-coordinate is read from the grid lines (A to K). The y-coordinate can be taken by counting 1 m steps along the lines. The useful range is defined as the most distant grid line (A to K) where the first signal was detected and a reliable positioning of the transmitter was possible. It is recommended to test all three possible coupling positions.

3.2 Multiple burial

To test the function of marking two beacons along the search path and from different producers, where both beacons have a different coupling position, the setup in Figure 5 is used.

One approaches the first transmitter using a receiver beacon and marks it as usual for the point positioning.

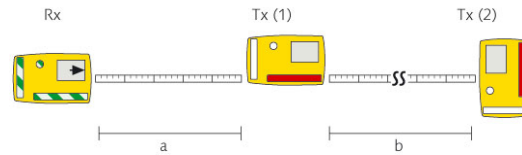


Figure 5: Experiment setup for the functional verification of the marking function of beacons. Two beacons with different coupling orientation are positioned after each other along the search path.

Then the measurement pulses are counted until the receiver suggests a new search direction to the next transmitter. The distance "a" between the recipient and the first transceiver is best chosen as 10 meters. The distance "b" between the two transmitters can now be varied. It is advisable to start at a practical distance of $b=25\text{m}$. Then the initial value of b is varied (20 m, 15 m, 10 m, 5 m) and the results of the measurement impulses are compared.

3.3 Strength of the third antenna

The range of the third antenna can be verified by an experiment setup where the receiver is forced to exclusively use its third antenna (see Figure 6). A transmitter is mounted on a wooden pole vertically above the snow surface (up to 5 m). Right below the transmitter, a line is defined on the snow surface reaching 10 m in both directions. The transmitter is now approached on the line with an initial distance of 10 m. The positions with the shortest displayed distance (signal maxima) are marked.

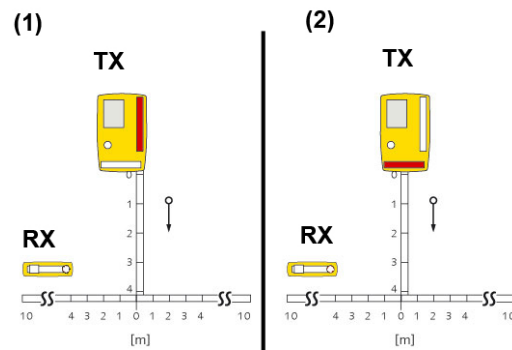


Figure 6: Experiment setup for the functional verification of the third antenna. On the left, a vertical beacon is tested, and on the right, a horizontal beacon is tested. See also Figure 3.

A correct 3- antenna beacon will show only one point with the shortest displayed distance. Next, the distance between the transmitter and receiver is decreased by shortening the wood pole and the test procedure is repeated. A second possibility is to position the transmitting beacon in a horizontal orientation so that the antenna points at the receiver. The receiving beacon is held vertically so that only the third antenna receives a signal. However, not all devices allow for this method since some beacons need to be held horizontally. A sample result of a beacon test is shown in Figure 7.

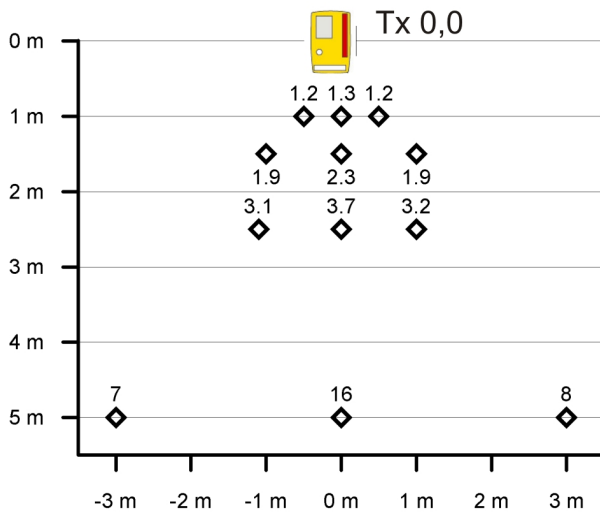


Figure 7: Results of a functional review of the third antenna of a beacon. The transmitter is located at 0,0. The positions of the squares show the signal maxima and minima. The numbers indicate the reading of the beacon with the ineffective third antenna.

With these three different experimental arrangements, the basic functions of modern 3 antenna beacons in the field can be reviewed and compared.

5 INTERPRETATION & DISCUSSION

The results of the chessboard test show the profiles of the various 3-antenna beacons. Due to the different interactions of the individual antennas of each unit, variations of the search paths occur. The device ranges derived from these experiments can be used for the estimation of the search strip width. It is recommended to use a search strip width twice the useful beacon range at the worst coupling position (Schreilechner et al. 2009).

In multiple burials, marking the already located transmitters is an important time saving factor for the rescuers. However, there are differences in the quality and handling between the marking functions of different devices. For example, the test setup with transmitter 1 with 457 kHz, ± 0 Hz and transmitter 2 with a slight frequency offset (e.g. 40 Hz) is handled insufficiently by some devices. To verify the operability, the combination of various transmitters should be tested in an experiment. The individual receivers react very differently to varying transmission characteristics between 2 transmitters.

Unfortunately, the third antenna in some beacons works only for very short (~ 1 m) distances, see Figure 7. Even with shallow buried avalanche victims, this would produce multiple maxima, even though the user wanted to avoid this phenomenon with the purchase of a 3-antenna device. The third antenna of modern transceiver should offer a minimum range of 5 m, so that multiple maxima can be avoided.

In an emergency, avalanche beacons must support the rescuer in the best possible way:

- 1) With a large, ideally circular coverage and therefore a correct direction indication from the initial detection (check with chessboard test)
- 2) With the display of only one maximum using the method of point positioning (one point, where the shortest distance is displayed) independently from the coupling location and burial depth (to be checked by using the pole test)
- 3) Through a reliable marking function of at least three beacons for quick rescue in multiple burial scenarios (verification with "Mark-test").

6 LITERATURE

- Eck, M., Schober, M. and Schreilechner, M., 2008. New definition of the useful range using a reliable, accurate, and reproducible test procedure with practical relevance – running a field test tracked by a DGPS. Proceedings ISSW 2008. International Snow Science Workshop, Whistler, BC, Canada.
- Genswein, M. and Schweizer, J., 2008. Numerical stimulation of the survival chance optimized search strip width. Genswein, Meilen, Schweiz and WSL Institute for Snow and Avalanche Reserach SLF, Davos, Switzerland.
- Meier, F., 2001. Determining the Width of a Search Strip for Avalanche Beacons. Eglisau, Switzerland.

- Schreilechner, M., Eck, M., Schober, M., 2009. Updating and Expansion of a Field Study to Optimize the Search Strip Width of Avalanche Beacons. International Snow Science Workshop, Davos, Switzerland.
- Schweizer, J., 2007. Determining the search strip width based on range measurements. SLF Davos, Switzerland.
- Schweizer, J. & Krüsi, G., 2003. Testing the performance of avalanche transceivers. Cold Regions Science and Technology 37, 429-438.
- Semmel, C., 2007. Stellungnahme der DAV-Sicherheitsforschung zur Bestimmung der optimalen Suchstreifenbreite.