Updating and Expansion of a Field Study to Optimize the Search Strip Width of Avalanche Beacons

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ABSTRACT: The range of an avalanche beacon depends on certain technical characteristics of the device and the position of the transmitter (or victim) relative to the receiver (or rescuer). To correct the effects of different coupling positions, some beacon manufacturers require various moving activities during a search, such as turning, rotating, and swinging. However, the methodology is unclearly defined by the manufacturer and makes it difficult for the search team to follow. Additionally, search strip widths are defined differently by different manufacturers of avalanche beacons and thus it is difficult for users to know which width to use. As a result of these factors, the devices are often used incorrectly or inadequately.

An extensive field study was performed in order to determine the ranges of all commercially available multi-antenna beacons in different coupling positions. The different runs were executed without moving any of the beacons in order to avoid changes in the coupling positions. The search paths, given by the direction and distance indicators of the beacons, were recorded with a differential global position system in sub-decimetre resolution. The results define useful ranges of beacons, independent from personal management of these beacons. The results differ from the manufacturers' manuals and suggest that further discussion is necessary for the determination of a sufficient search strip width.

KEYWORDS: Avalanche beacon, Useful range, DGPS, Search strip width

1 INTRODUCTION

The recommendations of the search strip width vary dramatically between manufacturers. The different methods used by the manufacturers depend on varying definitions of the useful ranges for search strips and on the different types of beacons used. In the past, mostly one- and two-antenna beacons were considered to determine the search strip width. However, in this study, the four commercially available three-antenna beacons were studied to determine their useful ranges with different antenna orientations from the transmitter to the receiver.

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

Their studies concentrated on a statistical approach to calculate the search strip width for the parallel/coaxial antenna orientation for a three-antenna beacon from transmitter to receiver using the following equation:

$$w = 1.26 \cdot \left(\bar{r}_{\max} - 2\sigma_{\max}\right)$$

This method requires that all beacons have the same characteristics in their receiver mode. By running the following field test, it can be shown that the receiver characteristics, or rather the interplay between the different working antennas, are noticeably different between different beacons.

In a previous field study (Eck, et al, 2008), all commercially available multi-antenna beacons were evaluated. However, new beacons with new software version have become available and continued testing was necessary. With the development of these new three-antenna beacons, the discussion continues for how to determine the useful range and the search strip width. The following study should be a contribution to this ongoing discussion.

2 BACKGROUND

The worst case scenario is when the victim is completely buried and the rescuer has to start the search without receiving any signal from the victim's avalanche beacon. In order to search for the first signal as a single rescuer, the rescuer must cover the avalanche field with meandering shape tracks until the first signal is received. If there is more than one rescuer available, then a parallel search array is possible in order to save time. In both situations, the rescuer(s) must know the useful range and, when recommended by the manufacturer, the required movements or

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motions of his or her beacon in order to determine the most effective search strip width (see Figure 1).

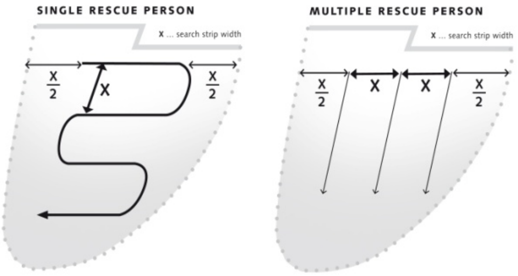

Fig 1. Scenarios with single rescuer (left) and multiple rescuers (right). x → search strip width

Using a smaller search strip width increases the probability of detecting the victim, but requires more time to cross the avalanche terrain. A larger search strip width reduces the search time, but the rescuer risks not receiving a signal from the victim.

Theoretically, the search strip width is two times the useful range of a beacon. The useful range depends on three conditions: signal properties, beacon characteristics, and the coupling position of the beacons. First of all, the signal properties (amplitude, frequency and pulse width) of the transceiver beacons determine the characteristics of the transmitted field. Secondly, the characteristics of different types of receiving beacons (one-, two- or three-antenna beacon) are important in receiving the transmission. Finally, the coupling position from the transceiver to the receiver also affects the results. Assuming that the rescuer is holding his or her beacon correctly (horizontal with the display on top), three different theoretical coupling positions are possible.

The first coupling position is when the transmitting antenna is parallel/coaxial with the strongest receiving antenna, and is known as the best coupling position. For the most part, in two and three-antenna beacons, there is one antenna that has the best receiving characteristics. For this reasoning, most of the beacons have elliptical receiving characteristics and this is why some manufacturers recommend turning, rotating, or swinging the receivers in order to help catch the first signal more quickly. However, these requirements are weakly defined and are rarely used correctly by users.

The second coupling position is when the transmitting antenna is perpendicular to the strongest receiving antenna and is known as the bed coupling position.

The third coupling position is when the transmitting antenna is in a vertical position and so the electro-magnetic field has the weakest strength. This is the worst case scenario. The real positions of the transmitter and receiver will be a combination of these three theoretical possibilities.

3. FIELDWORK AND METHODOLOGY

A square of 50 x 50 m was used for the investigation area for the field study. The square was divided into 5-m wide strips and a transceiver was positioned at the bottom left corner (coordinates x=0, y=0 at Fig. 3 to Fig. 5) in three different antenna orientations (parallel/coaxial, perpendicular and vertical). The rescuer, with a receiver, walked along the predefined 5-m strips directly followed by a second person with a Differential Global-Positioning-System (DGPS). This made it possible to record the accurate track (to the nearest 5 cm) of each search path. The rescuer started at a distance of at least 50 m from the transmitter, always using the same receiver orientation (azimuth). Until the rescuer received the first signal, the 5-m strips were used as his or her path. After receiving the first signal, the path was determined according to the displayed signal on the beacon. This was down without turning, rotating, or swinging the receiver. The only change for the three different trials was the orientation of the transmitter.

A NovAtel DL-4 DGPS receiver with an integrated memory card was used for data logging. The position of the receiver was recorded every second with an accuracy of a few centimetres. The data was processed with waypoint Graph 7.8 in a post processing mode that produced a database for plotting and interpretation of the paths in one-second intervals.

The field study was performed in February 2009 with all commercially available multi-antenna beacons with their most current software versions. In this report, three-antenna beacons are presented in three different antenna orientations of the transmitter.

4 OBSERVED DATA

The data is plotted as maps with the different observed trajectories, see Figures 4 to 6. The axes of the maps are dimensioned in metres. The transmitter beacon is placed on the left bottom corner with the coordinates (0,0). The rescuer started at the top line with a predefined distance of 5-m in the x-direction. The results are summarized in Table 1. On each figure, the numbered points indicate the first received signal. The legend on the right gives the number of the point and the displayed data at this time (d=distance, a=azimuth for the direction indicated on the device and L=lost the signal) and the calculated distance to the transceiver (separated by a semicolon).

4.1 Trajectories in good coupling position

The transmitter is orientated horizontally and the receiver and transmitter are parallel/coaxial. Parallel/coaxial means that the receiver and transmitter have the same azimuth.

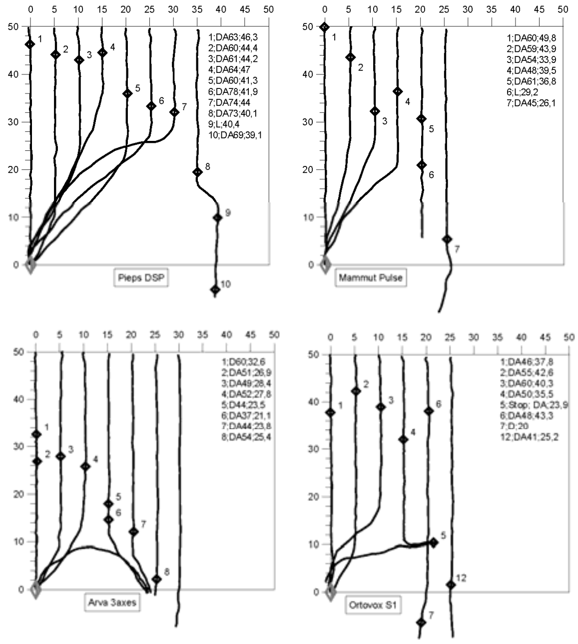

Fig 3. Trajectories of four different 3-antenna beacons in good coupling position. The numbered points indicate the first signal and are discussed in the text. The useful range of the beacons, clockwise from the top left are 30 m, 15 m, 20 m, and 15 m.

4.2 Trajectories in bed coupling position

The transmitter is orientated horizontally and the receiver and transmitter are perpendicular to each other.

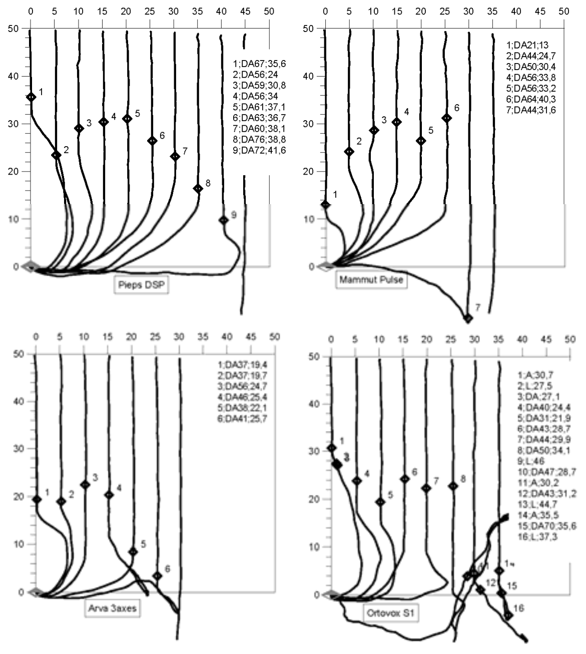

Fig 4. Trajectories of four different 3-antenna beacons in bed coupling position. The numbered points indicate the first signal and are discussed in the text. The useful range of the beacons, clockwise from the top left are 40 m, 30 m, 25 m, and 25 m.

4.3 Trajectories vertical transmitter position

The transmitter is orientated vertically and the antennas of the transmitter and the receivers are perpendicular in the third dimension to each other.

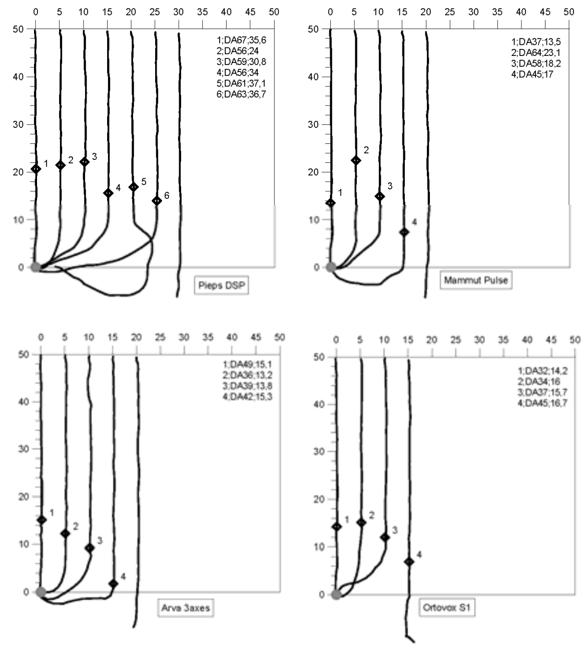

Fig 5. Trajectories of four different 3-antenna beacons with a vertical transmitter antenna. The numbered points indicate the first signal and are discussed in the text. The useful range of the beacons, clockwise from then top left are 25 m, 15 m, 15 m, and 10 m.

	Pieps DSP	Mammut Pulse	Arva 3axes	Ortovox S1
gc	30	20	20	15
bc	40	30	25	25
vc	**25**	**15**	**15**	**10**
rs	50	50	40	50
es	**50**	**30**	**30**	20
r_{max}	*46.3*	*49.8*	*32.6*	*37.8*
w	*58.3*	*62.8*	*41*	*47.6*

Tab 1. Comparison of the useful ranges of the tested beacons in metres.

gc → good coupling position = parallel/coaxial
bc → bed coupling postion = perpendicular
vc → vertical coupling position = perpendicular in 3 dim.
rs → recommended search strip width from manufact.
es → search strip width derived from this study
r_{max} → maximal range in parallel/coaxial antenna configuration
w → search strip with 1.26 r_{max}

The bold values are the minimal ranges in respect to each beacon and give the effective search strip width as the double of the DGPS-derived useful range.

6 INTERPRETATION & DISCUSSION

The search strip width is usually defined as twice the useful range. However, the useful range of different types of beacons is not consistently defined.

Different manufacturers are using different approaches to define the search strip width for their own products, thus making the recommended search strip widths incomparable. The main reason for this is that the three antennas have different useful ranges and are dependent on the beacon used. In other words, it is important to establish how the three antennas work together with their internal processing system and to determine how the result is shown as a distance and azimuth display. The assumption that the worst case scenario is with the vertical transmitter position (Meier, 2001) is only valid for one- and two-antenna beacons. In the presented field study, the realistic search strip width is determined using data from all three antenna positions for each individual beacon. It is imperative that the correct signal is displayed in order for the rescue mission to be successful. In the above figures, the correct signals are indicated as the numbered points in each track. These results will yield a correct distance indication on the display as soon as a beacon receives a signal.

A statistical approach is generally acceptable if the same values with the same sources are compared. But in our case, with three-antenna beacons, the interaction of the three antenna positions is different.

Unfortunately, only one run for each beacon with the parallel/coaxial antenna configuration was recorded, and therefore, it is not possible to calculate any statistical value like the standard deviation, σ_{max}, to determine the proposed search strip width like in Meier (2001). The previously calculated values from Meier's equation, $w = 1.26 \cdot (\bar{r}_{max})$, were much higher than the values determined in the presented study. The reliable distance and azimuth display were not considered in Meier's study, however these factors are essential properties of the beacons and must be considered in determining the realistic search strip width.

7 SUMMARY & CONCLUSIONS

The presented study shows a method to determine the search strip width in respect to the interaction of all three antennas and the azimuth and distance indication on the display. Only three-antenna beacons were considered. These results should provoke further discussion on how to determine the search strip width. Since the characteristics of several multi-antenna receivers are different, it is not acceptable to calculate a realistic search strip width based on a single equation. It is necessary to run field tests with different antenna configurations in order to determine the search strip width.

7 ACKNOWLEGMENTS

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