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

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ABSTRACT: We have used a Differential Global Positioning System (DGPS) for tracking the search trajectories of a rescuer at three different orientations of the antenna of a transmitted beacon. Hence, it is possible to determine the useful range of the width of search strips for different beacons. All commercially available (digital) beacons in Winter 2007/2008 were tested at a 50 x 50 m area in a field study. As examples three runs of two beacons with different antenna positions of the transmitter is presented. A buried transmitted beacon with a vertical orientation of the antenna represents the worst case scenario for determining the search strip width.

KEYWORDS: Avalanche beacon; Useful range; DGPS; Field study; Coupling position; Search strip width

1. INTRODUCTION

In February 2006, the French ANENA (Association Nationale pour l'Etude de la Neige et des Avalanches) started a discussion about the value of the search strip width and about the so-called "Useful Range". This was the beginning of a still ongoing discussion with several organizations involved. In autumn 2006 the ICAR started the discussion about "how to find a common procedure to determine the search strip width". In February 2007 Chris Semmel (DAV Sicherheitsforschung; Munich) publicized his statement and results, based on the measurements of the minimum receiving range. Also in February 2007 Juerg Schweizer (SLF; Davos) started his analysis (initiated by the ICAR) about "Determining the search strip width based on range measurements" and presented the result at the ICAR meeting 2007 in Pontresina (CH).

Till now, no consensus exists about which of the existing measuring and analysis methods is the most practical.

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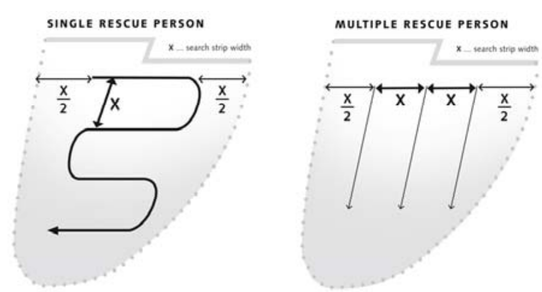
2. BACKGROUND

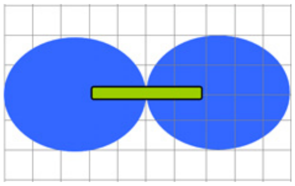
The worst case scenario in the case of a slab avalanche is, when your partner is buried totally and you start your companion rescue without a receiving signal on your beacon. To search for the first signal as a single rescue person, the rescuer has to cover the avalanche field with meander shaped tracks until he gets the first detecting. If there are more than one rescue person are around to help, they safe time in going down the slab in parallel tracks. Doing this, each rescuer has to maintain the maximum search strip width (distance between the tracks of the rescuer/s) of his beacon.



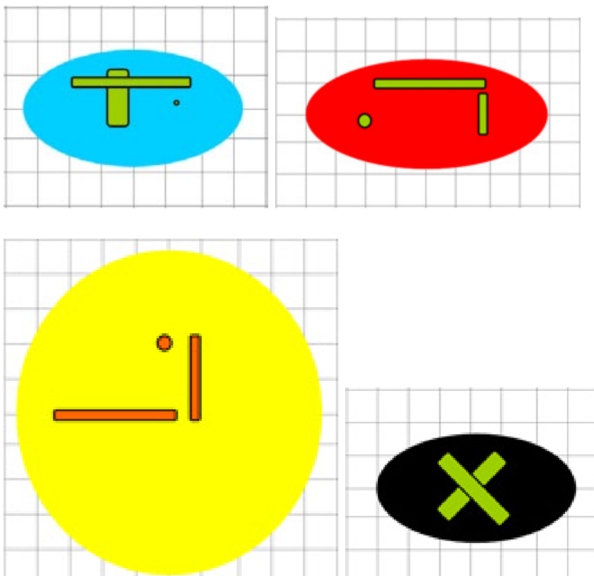
Picture 1: Single rescue person and multiple rescue people

Using a smaller search strip width would mean to spend much more time (running a longer way).
Also the rescuer must have a look on it, not to increase this max. search strip width. In this case the possibility is very high, not to detect the transmitter and miss the victim (loosing time), while moving over the avalanche. The available beacons now, have an elliptic up to a circular

receiving range (assists you most), because of the numbers and sizes of the different antennas and the technical performance inside the beacon.



Picture 2: Typical receiving characteristic of a 1-antenna beacon



Picture 3: Different characteristics of beacons with more than one antenna. A direction indication is given to the rescuer.

To cover the recommended search strip width of a manufacturer, the rescuer has to know exactly how it has been defined and how his beacon is working.
An example: The receiving beacon has an elliptic receiving range. A) The direction indication starts as soon as a receiving signal is detected on antenna -x and –y.
B) Before getting a signal on the second antenna the beacon works like a 1-antenna beacon (bigger range)
If the recommended search strip width depends on A), the rescuer has to use a special kind of work (turning around), not to miss the victim. If it is A), the rescuer has to run a longer distance, but must not think about the kind of work in this situation of stress.

So at the time the advertised maximum search strip width by the manufacturer, depends on the method the manufacturer uses and its practical philosophy: "Maximum search strip width is the range within a direction indication is shown on the display and the rescuer must not think about how to handle his beacon to cover the given maximum search strip width" - or "The maximum search strip width is the max range the rescuer reaches if he combines the technical performance (max possible range) of his beacon with an optimal kind of work."

There are significant differences in recommendations of the search strip width in the international literature. Most beacons have a range of 60 to 80 meters, but some digital display beacons have a range of half that because the microprocessor filters the audio signal (Temper 2001). One person can search for signals by making traverses 20 m apart and 10 m from the edge of the deposit (Jamieson 2000).
This is the reason why the search strip width is one of the most determining factors for your overall searching time.

There are a vary of approaches, either based on measurement of the range in best coupling position and following mathematic reductions, or range tests using all different positions, while only the worst results are taken into account.
Since there it seems to be no common understanding in the near future, we decided to describe, perform and analyze a new approach:
Based on an avalanche field, divided like a chess field, beacons searches has been performed and tracked using a DGPS with an accuracy less than a couple of centimeters. Analysis, done afterwards, provides very interesting and highly relevant results.

3. FIELDWORK AND METHOLOGY

A square of 50 x 50 m was used for the investigation area for the field study. This square was divided into 5 m wide strips. A digital transmitter was positioned at a corner of the square in three different orientations of the antenna. A person with a receiver beacon walked along the predefined strips with distances of 5 m. The searcher was directly followed by a second person with a DGPS receiver (see Fig.1). Therefore it was possible to record the accurate track which was used from the searcher. Until to receive the first signal, the 5 m strips were used as path like the search strips. After receiving the first signal a path according the displayed signal of the beacon was followed and recorded.

Figure 1: The searcher was directly followed by a second person with a DGPS receiver.

A NovAtel DL-4 receiver with an integrated memory card for data logging was used as DGPS instrument. Every second the position of the beacon was recorded with an accuracy of few centimeters. The data were processed with Waypoint GrafNav 7.8 in a post processing mode. So, a database for plotting and interpretation of the path of the searching beacons is available in one-second steps.

For every tested beacon three runs were done. These runs vary in three different orientations of the transmitter beacon in relation to the receiver beacon. The first run (chapter 4.1) was done in a so called "good coupling position". The antenna of the transmitter beacon has the same orientation (same azimuth) as the receiver beacon. The second run (chapter 4.2) was done with a so called "bad coupling position". The antenna of the transmitter beacon is perpendicular to the antenna of the receiver position. But both antennas are horizontal orientated. The third run (chapter 4.3) was done with the so called "worst coupling position". The antenna of the transmitter beacon is vertical orientated.

With these three different antenna orientations all in Winter 2007/2008 commercially available (digital) beacons with two or three antenna were tested. In this report only two beacons are presented in three different antenna orientations as examples.

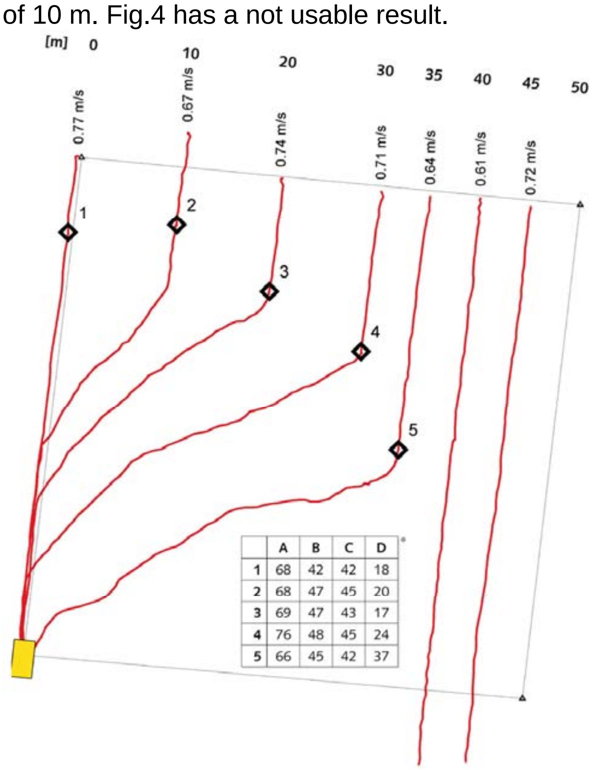
4. OBSERVED DATA

The data are plotted as maps with the different observed trajectories. On each top of a map the average velocities is shown in meter per second and the distance W to E is given in meters. The first observed signal with a reliable direction and distance information of the beacons is marked with a symbol and a number. The number indicates in the legend. At the legend of each run, different results are described. The first number (A) indicates the distance readings of the display of the beacon. The second number (B) gives the length of the trajectories to the transmitter in meters. The third number (C) shows the length of the direct path to the transmitter in meters. (A,B,C measurement starts at the symbol and number till the transmitter). The fourth number (D) informs us about the expired time from the start position to the current position in seconds. As examples in this chapter the beacons with the highest and the lowest distance form the transmitter to the receiver are showen as graphs. The other results are presented as Table 1.

4.1 Runs with good coupling position

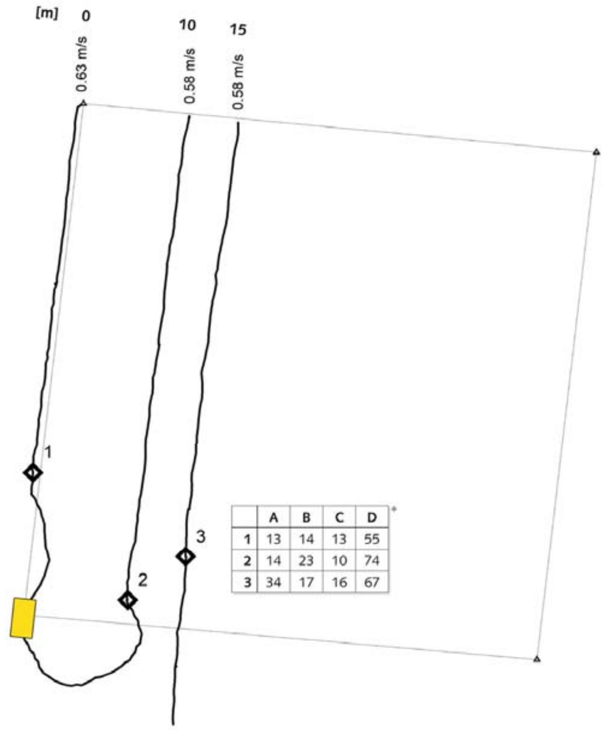
The transmitter is horizontal orientated. The antenna of the transmitter and the receiver are parallel or sub parallel. At the left most run at the Fig. 2 and 3 is conforming to a coaxial coupling of the receiver and transmitter antennas.

The beacon of Fig. 2 has a useful range of 35 m whereby the beacon of Fig. 3 has a useful range of 10 m. Fig.4 has a not usable result.



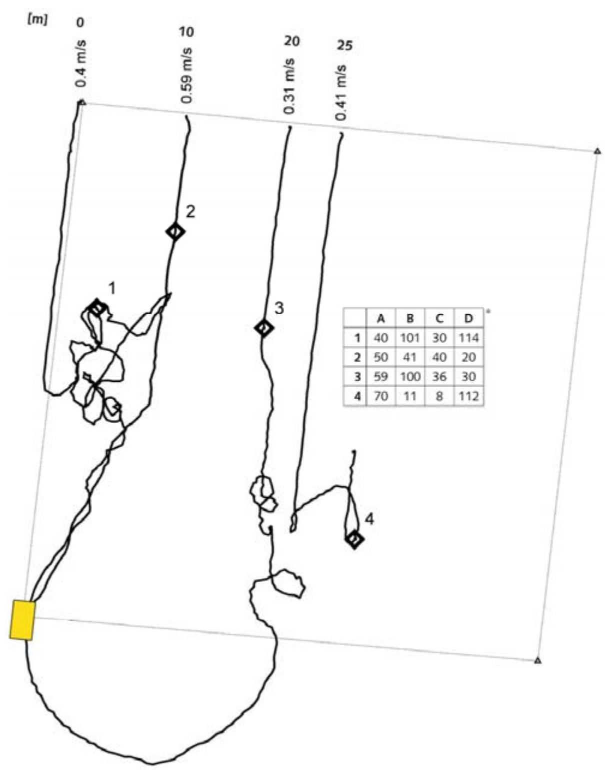
	A	B	C	D
1	68	42	42	18
2	68	47	45	20
3	69	47	43	17
4	76	48	45	24
5	66	45	42	37

Figure 2: Trajectories of a beacon with big useful range with a horizontal transmitter in a good coupling position.



	A	B	C	D
1	13	14	13	55
2	14	23	10	74
3	34	17	16	67

Figure 3: Trajectories of a beacon with a small useful range with a horizontal transmitter in a good coupling position.

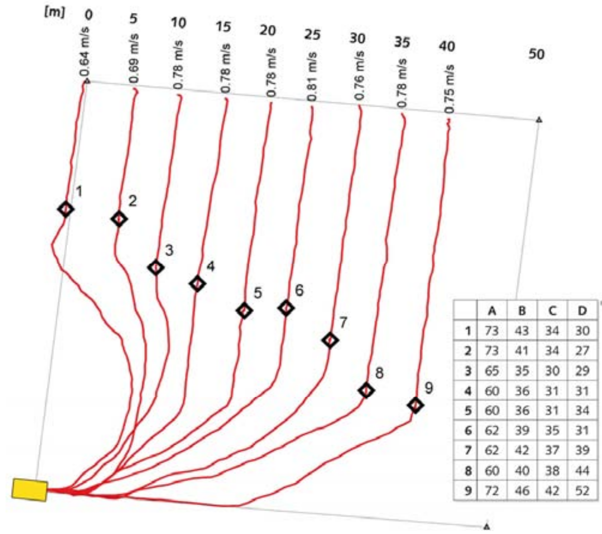


	A	B	C	D
1	40	101	30	114
2	50	41	40	20
3	59	100	36	30
4	70	11	8	112

Figure 4: Trajectories of a beacon with no useful range with a horizontal transmitter in a good coupling position

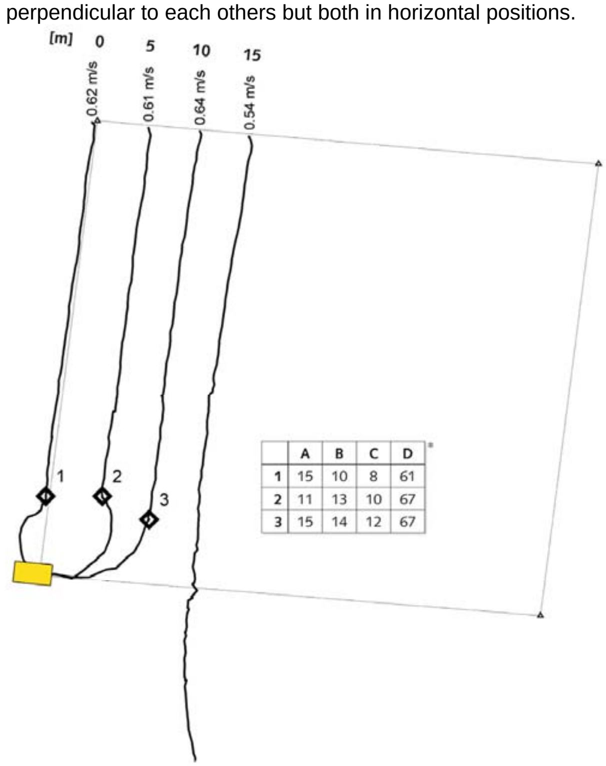
4.2 <u>Runs with bad coupling position</u>

The transmitter is horizontal orientated. The antennas of the transmitter and the receiver are perpendicular to each other.
The beacon of Fig. 5 has a useful range of 40 m whereby the beacon of Fig. 6 has a useful range of 10 m. Fig.7 has a not usable result.



	A	B	C	D
1	73	43	34	30
2	73	41	34	27
3	65	35	30	29
4	60	36	31	31
5	60	36	31	34
6	62	39	35	31
7	62	42	37	39
8	60	40	38	44
9	72	46	42	52

Figure 5: Trajectories of a beacon with a big useful range with a horizontal transmitter position, whereby the antennas are perpendicular to each others but both in horizontal positions.



	A	B	C	D
1	15	10	8	61
2	11	13	10	67
3	15	14	12	67

Figure 6: Trajectories of a beacon with a small useful range with a horizontal transmitter position, whereby the antennas are perpendicular to each others but both in horizontal positions.

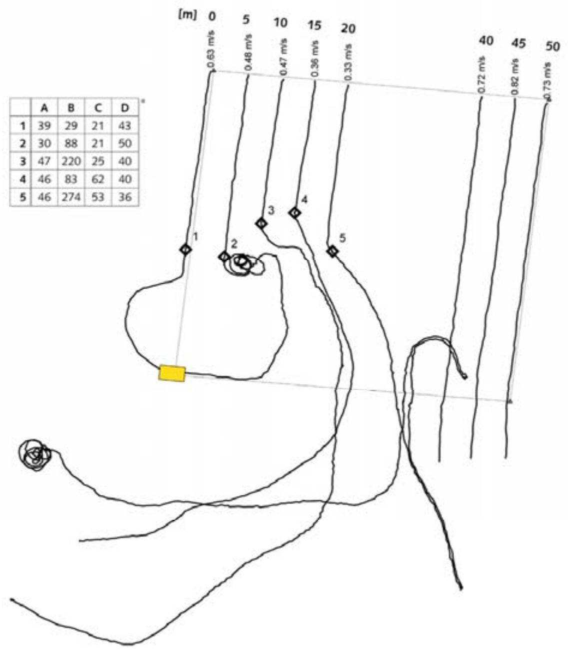


Figure 7: Trajectories of a beacon with no useful range with a horizontal transmitter position, whereby the antennas are perpendicular to each others but both in horizontal positions.

4.3 <u>Runs with vertical transmitter position</u>

The transmitter is vertical orientated. The antennas of the transmitter and the receiver are perpendicular in the third dimension to each other. The beacon of Fig. 8 has a useful range of 30 m whereby the beacon of Fig. 9 has a useful range of 5 m. Fig.10 has a not usable result.

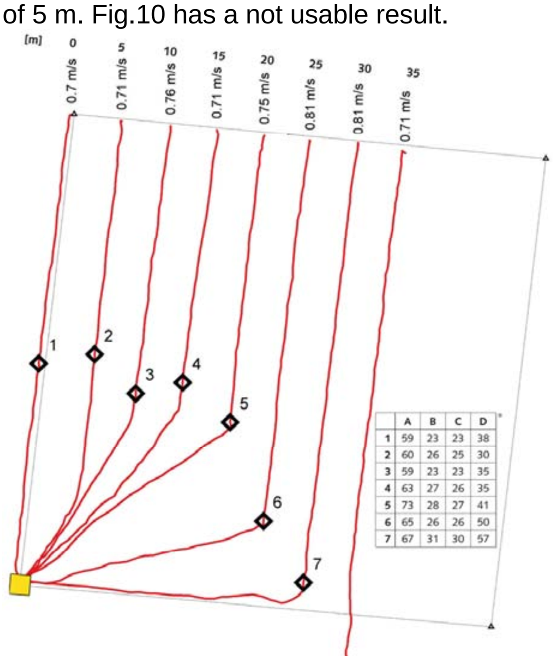


Figure 8: Trajectories of a beacon with a big useful range with a vertical transmitter position whereby the antennas are perpendicular to each other.

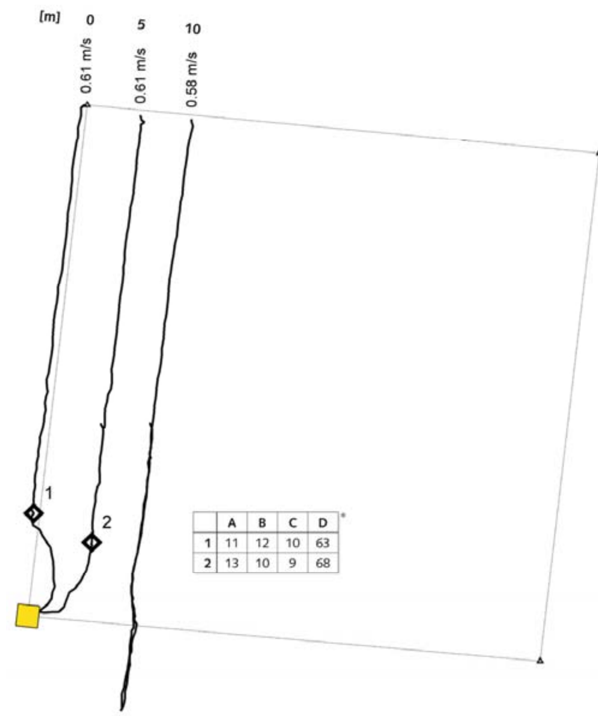


Figure 9: Trajectories of a beacon with a small useful range with a vertical transmitter position whereby the antennas are perpendicular to each other.

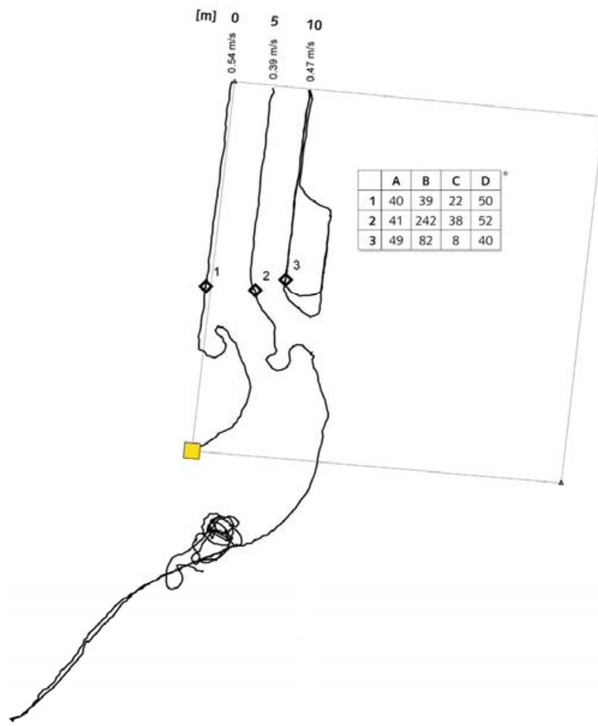


Figure 10: Trajectories of a beacon with no useful range with a vertical transmitter position hereby the antennas are perpendicular to each other.

	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10
v	**15**	**10**	**30**	**15**	**10**	**10**	**20**	?	**10**	**5**
bc	25	15	40	25	20	15	30	?	20	15
gc	20	15	35	20	15	10	25	?	15	10
rs	40	30	50	30	40	40	50	50	20	40
es	**30**	**20**	**60**	**30**	**20**	**20**	**40**	**?**	**20**	**10**

Table 1: Comparison of the useful range of the tested beacons in meters.
v → vertical coupling position of the beacons
bc → bad coupling position of the beacons
gc → good coupling position of the beacons;
rs → width of search strip, recommended by the manufacturer.
es → effective search strip based on DGPS-method

The bold numbers are the minimal ranges in respect of each beacon and gives us the effective search strip width (the double). In this chapter the beacons B3 and B10 are shown. The results of B8 are not useable to get a useful range.

5. INTERPRETION AND DISCUSSION

The search strip width is usually defined as maximal the double width of the useful range. But we have at the time no common and accepted definition of it.

Different manufacturers are using different approaches how to define the search strip width. Often this width can only be archived when the user is acting like using a 1-antenna beacon width all consequences (need of 3D turns…). Also, with some 2- or 3-antenna beacons different operation methods have to be combined.

We can assume that every user will hold his beacon horizontal in respect to be able to read the display. Because of this and because of the extraordinary situation of stress, the rescuer forgets a special, recommended kind of work mostly.

For us, the practical useful range depends on the coupling position and the max rang while running for the first signal without any special kind of work. In our test, and we think this in general, the vertical coupling position (between transmitter and receiver) is the worst case scenario. We think it shows us the practical "useful range" for the search strip width – independent of the technical performance.

From the presented data we can observe a big span of the useful range. The minimal useful range was 5 m, the maximum range was 30 m for the vertical transmitter orientation.

6. SUMMERY AND CONCLUSIONS

The final conclusion is, that given maximum search strip widths by manufacturers, can't be trusted in some cases and doesn't meet the requirements in an emergency rescue operation. As long as there is no common understanding and no common standard about how to determine the "useful range" or the "search strip width" some manufacturers will continue to provide wrong or irritating numbers for the "manufacturer recommended search strip width".

Therefore the authors propose that manufacturers of avalanche beacon have to recommend a search strip width derived from field tests (approach according 4.3) with a vertical orientated transceiver antenna. Recommended search strip width derived from theoretical considerations associated with good a coupling position are dangerous and not helpful.

Reliable information about one of the most important performance value of a beacon – the "useful range" or "search strip width" (which is 2x useful range) is fundamentally essential for buyers, rescuers and individuals.

7. ACKNOWLEGMENTS

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