THE EFFECT OF COMMUNICATION EQUIPMENT ON AVALANCHE TRANSCEIVERS

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The ongoing replacement of analog communication equipment by digital equipment as well as the general tendency of increased use of electronic devices while touring as well as in rescue is a constant challenge to the user. The possible sources of interference include analog/digital VHF and UHF radios, using FDMA or TDMA, as well gadgets such as PMR radios, GPS devices, smart phones and wrist watches.

The current avalanche transceiver technology is based on the concept of searching for buried subjects by following the flux lines of a 457 kHz transmitter. Interference related complications in rescue have been reported and are caused by portable electronic devices, communication equipment or metal objects such as carabiners, ice screws etc.

In order to systematically analyze how the transmit mode may be compromised and the receive mode may suffer loss of range or show unreliable distance/direction indications, a laboratory study has been carried out.

Based on measurements in an EMC (Electro-Magnetic-Compatibility) laboratory, the study provides results about how different communication equipment influences the transmit [SEND] and receive [SEARCH] modes of an avalanche transceiver. For devices which are critical in rescue, such as communication equipment, the study evaluates the required safety distances in order to allow the use of such devices on the accident site while a search is being conducted.

The study provides a better level of understanding concerning interference issues and recommendations how to avoid situations which may lead to problems in the field. The measurements indicate that the interference is depending on the transmit mode or frequency of the communication device.

KEYWORDS: Avalanche Transceiver, Electromagnetic Compatibility, Interference, Rules concerning interference

1 INTRODUCTION

An avalanche transceiver is designed to search for buried subjects within a maximum range of approx. 70 meters (digital), using the internationally standardized frequency of 457 kHz.

The avalanche transceiver of the buried subject transmits a 457 kHz signal about once per second. ETSI EN 300718 (2018) defines the technical requirements for avalanche transceivers and ensures compatibility between them.

The rescuer with the receiving avalanche transceiver follows the flux lines of the magnetic field of the transmitter for locating a buried subject.

In recent years, users of avalanche transceivers have started to replace there analog communication equipment with digital devices. At the same time a general tendency to increased use of electronic devices while touring as well as in rescue situations has been observed in the mountains.

It is important to understand that any type of communication equipment or electronic device emits electromagnetic noise, even if it is EMC tested according to international standards.

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These emissions do not occur in a specific frequency range, they are a broadband phenomenon, with sporadic and stochastic parts. A variable amount of this noise may overlap with the frequency band of a receiver. Therefore, this low-level noise may possibly disturb a sensitive receiver if the distance to the noise source is very small as reported in the ISSW Paper “The Effect of Consumer Electronics on Avalanche Transceivers” by Meister and Dammert (2014).

Communication equipment, for example radio transceivers, additionally emit their transmit signals at a high power level. Their antenna radiates this signal in a specific frequency range, far away from the 457 kHz of the avalanche transceivers, the frequency of a PMR radio at 446 MHz e.g. is almost 1000 times higher.

The antenna and the receiving circuit of the avalanche transceiver act as a suppression filter for unwanted frequencies, but are not perfect and there may be some parasitic elements in the circuitry that make the receiver less than ideal. The interference potential of a transmitter therefore is depending on the layout of the receiver’s circuit.

Every transmitter emits some unwanted electromagnetic noise apart from the intended transmitter signal. This may be related to the transmitter signal modulation, or it may be related to the other electronic circuits.

The goal of this study is to show the different interference levels of different radio transmitters, and to provide a better level of understanding concerning interference issues for the different user groups of avalanche transceivers. The conclusions include recommendations on how to avoid situations which may lead to problems during companion rescue or in an organized rescue mission.

2 BACKGROUND

This study focusses on handheld communication equipment (radio transceivers). Their intended purpose is to emit an electromagnetic field when in transmit mode. Therefore it is expected that these devices do have an influence on the performance of the highly sensitive receiver of an avalanche transceiver, especially when operated close-by.

Radio transceivers have to comply with national and/or international standards. They operate in allocated frequency bands. Today, different generations of radio transceivers are in use, simple analog and complex digital devices.

In this context “analog” and “digital” are vague specifications, since every emitted signal is analog, but it may carry analog or digital coded information, and the link connection may be simple push-to-talk or controlled by a microprocessor.

In analog radios, the carrier frequency is modulated (FM) with the analog microphone signal. The amplitude of the emitted signal is constant during the call.

Digital radios convert the microphone signal to a digital data stream before modulating the carrier, mostly by using phase modulation (PM). With digital modulation it is possible to transmit digital data, even with encryption. PM, similar to FM, results in a constant amplitude of the emitted signal during a call or a time slot (see below TDMA).

To allow multiple users or user groups to make use of the same frequency bands there are two different standardized techniques available:

FDMA (frequency division multiple access)

On different frequencies, called channels (separated by a specified frequency step, e.g. 12.5 kHz), several calls may be established at the same time. The amplitude of the emitted signal (FM or PM) is constant during the entire call (Fig. 1).

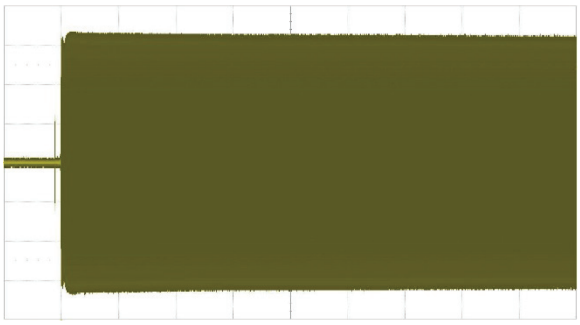

Figure 1: FDMA transmitter signal.

TDMA (time division multiple access):

The same frequency may be used by several users at the same time. They get assigned a time slot in a sequence to transmit their compressed information. The receiver decompresses the incoming signal, the user doesn’t notice anything of this process. The amplitude of the emitted signal is changing according to the assigned time slots.

Figure 2 shows a signal of a TDMA transmitter (Tetra), the scale is 100 ms/div. The length of the time slots is about 14 ms; each time slot contains about 5 Mio. sine waves of the PM carrier frequency with constant amplitude (not visible in Fig. 2):

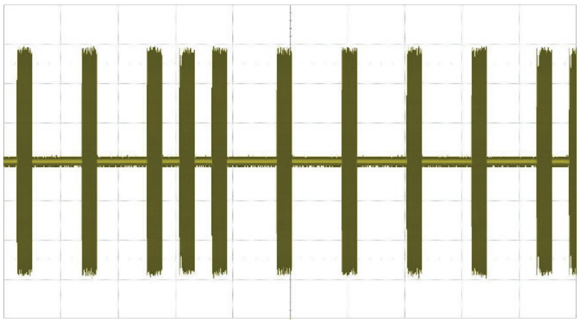

Figure 2: TDMA transmitter signal. Scale: 100ms/div with a time slot length of 14 ms.

In general there are two frequency bands used for handheld radio transceivers: the VHF or 2 m band (around 150 MHz) and the UHF or 70 cm band (around 400 MHz).

These two bands are divided into sub-bands, assigned to different user groups, depending on national or international regulations. Some of these sub-bands are available for use without a license but others are reserved for licensed users. The maximum permitted transmit power is also regulated.

PMR is a very often used term in this context – but can have several meanings as shown in Table 1.

PMR: Private Mobile Radio
PMR: Professional Mobile Radio, often used as a synonym for “trunked radio system”.
PMR446: Private Mobile Radio on 446 MHz, (unlicensed use throughout Europe). It is the European counterpart to the North American FRS standard (Family Radio Service).

Table 1: Different meanings for the very often used term PMR

A trunked radio system is based on a network of base stations and allows communication within the entire area of this network. It is shared by several user groups and can be operated as an FDMA or a TDMA System. It is possible to switch the radios into Direct Mode Operation (DMO) to allow communication between two radios without using a network base station.

TETRAPOL: is also a trunked digital professional mobile radio standard. It operates as a FDMA system in the UHF band. It is defined by the Tetrapol Publicly Available Specification (PAS).

POLYCOM: the Swiss national mobile radio network is based on the TETRAPOL standard.

TETRA: Terrestrial Trunked Radio, also originally known as Trans European Trunked Radio, is a professional mobile radio standard published by the European Telecommunications Standards Institute (ETSI). It operates as a TDMA system in the UHF band.

The TETRA standard is designed for use by government agencies, emergency services (police, fire departments, rescue organizations, …) for a public safety network. To run communication equipment within the TETRA standard requires a license from the national authorities.

Please note: the given overview of handheld communication equipment and frequencies is not complete and there may be more similar systems.

3 METHODS

We applied quantitative laboratory measurements with a number of different avalanche transceivers which were available on the market in the 2017/18 season (Tab. 2). In each test, different radio transceivers were placed in different positions and antenna orientations relative to the avalanche transceiver (Tab. 3).

A minimal test distance of 30 cm between the radio transmitter and the avalanche transceiver under test has been chosen for two reasons: on one hand at lower distances it would be impossible to specify a proper distance between the interfering radio antenna and the avalanche transceiver. And on the other hand it would be difficult to distinguish the interference of the transmit signal from the emissions of the radio’s electronic circuits (e.g. display, power supply, CPU, …)

3.1 Test Arrangements

A loop antenna is used for generating a magnetic field (H-field) signal, corresponding to the signal of a transmitting avalanche transceiver at a distance of about 45 m.

The avalanche transceiver in receive mode (SEARCH) is placed in the center of the loop antenna, with the X antenna at an angle of 30° to the direction of the magnetic field. In that way both the X- and the Y-antennas are part of the receiving system, and interference with either of them can be detected at the same time.

The radio transceiver is successively placed at 9 points along a half-circle around the avalanche transceiver at a distance of 30 cm (the distance is measured between the antenna feed point (radio transceiver) and the center of the avalanche transceiver).

Three different antenna positions of the radio transceiver relative to the avalanche transceiver were tested: in parallel with the X-antenna (Fig. 3), in parallel with the Y-antenna (Fig. 4), and finally vertical to the X-Y-plane (Fig. 5).

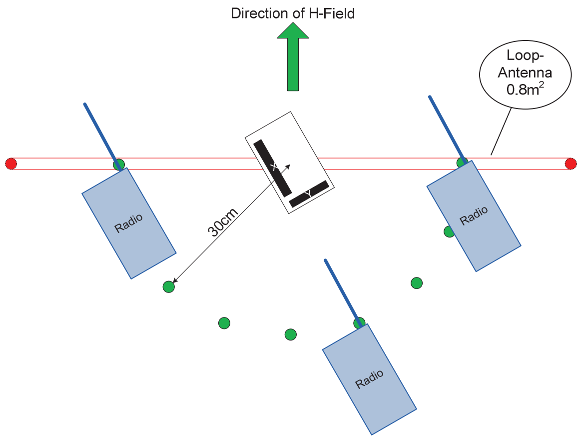

Figure 3: Antenna Direction - parallel to X-Antenna of the avalanche transceiver.

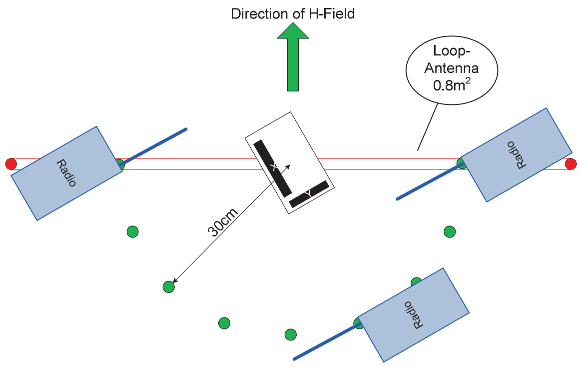

Figure 4: Antenna Direction - parallel to Y-Antenna of the avalanche transceiver.

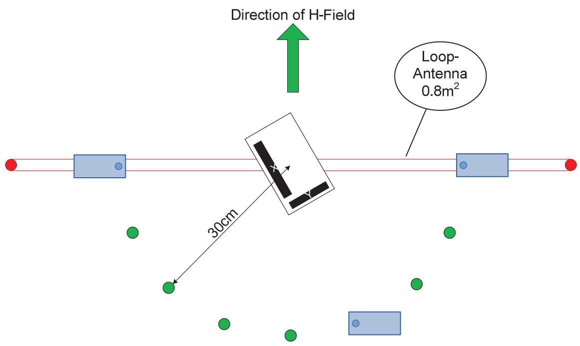

Figure 5: Antenna Direction - vertical to X-Y-Plane of the avalanche transceiver.

3.2 Test Conditions

We did the measurements with two different test setups for “SEND” and “SEARCH” Mode.

Signal search without an applied H-field signal

This test setup verifies false detection (ghost signals) by the receiving avalanche transceiver, caused by interference from the radio transmitter.

Signal search with an applied H-field signal

This test setup verifies if any interference caused by the radio transmitter leads to signal loss, range reduction of the receiving avalanche transceiver or erroneous distance and/or direction indication during a search.

The signal strength of the applied H-field is about 3 dB below the value which is set in the standard EN 300718 (2018) for minimum sensitivity of the receiver. It corresponds to a distance of approx. 45 m.

During these tests the radio transceiver was held in one hand while pressing the PTT key. The avalanche transceiver was resting in the center of the loop antenna. From time to time it has been kept in the other hand to check if there is an influence of the human body (e.g. the hand).

For the FM radios the PTT key was pressed at 1 s intervals to check if the avalanche transceiver is affected by the on-off keying of the transmit signal. This hasn’t been done with the Tetra radios, since their carrier is on-off keyed all the time, and the shortest transmit sequence is much longer than 1 s.

To exclude external interference during the measurements all tests were made in a shielded room. Therefore reflections of the radio transmit signal couldn’t be avoided; but since the tests were carried out in an extreme near-field situation (very close to the antenna) their influence is considered to be low. In the various testing positions and at different transmit frequencies the possible effects of the reflections also were different (increasing or reducing the interfering field strength).

3.3 TESTED AVALANCHE TRANSCEIVERS

Brand / Model	SW Rev.
Mammut Barryvox S	3.0
Mammut PULSE Barryvox	4.0
Pieps MICRO	2.5
Pieps DSP pro	2.0
Arva AXIO	1.5
Arva Neo	2.0
Ortovox S1+	2.0
Ortovox 3+	2.1
Tracker 3	1.1

Table 2: List of avalanche transceivers that have been tested.

4.4 TESTED RADIOS

Brand	Model	Modulation	Frequency [MHz]	Tx Power [W]
Motorola	GP380	FM	145 173	1 5
Motorola	DP3441e	FM	155	5
Midland	M-99S	FM	446	0.5
TEAM	TeCom-X5	FM	476	4
Sepura	STP9038	Tetra*	390	1.8
Motorola	MTP3550	Tetra*	421	1.8

Table 3: List of communication equipment (radio transceivers) that were tested. *Tetra radios were operated in Direct Mode Operation (DMO).

4 RESULTS

4.1 "SEND" Mode

Interference has been observed for some of the tested avalanche transceivers in relation to the distance (less than 10 cm) between the radio transceiver in transmit mode and the avalanche transceiver.

Remark: beside the fact that such a setup (radio transceiver in transmit mode carried close to a avalanche *transceiver in avalanche terrain) is not practical at all, it is nevertheless a high quality indicator for an avalanche transceiver.*

Influence of radio transceiver in transmit mode

Most avalanche transceivers performed well and were not disturbed by any radio transceiver. For one avalanche transceiver a system restart has been reported, caused by a 5 W VHF radio transmitter.

Influence of metal

The effect of metallic parts of a radio transceiver to an avalanche transceiver in "SEND" Mode would be similar to the results reported by Meister and Dammert (2014).

4.2 "SEARCH" Mode

The following figures show the influence of a TDMA radio transceiver (Tetra) on a receiving avalanche transceiver at different distances.

The signals measured during the tests were recorded by means of a PULSE Barryvox via its earphone jack. The horizontal scale of Fig. 6 is 0.2 s/div.

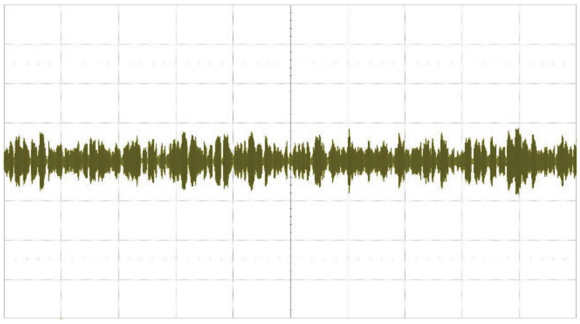

Figure 6: Noise floor / white noise of a Pulse Barryvox without any signal from a buried avalanche transceiver.

Figure 7 shows the pulsed 457 kHz H-field signal with an amplitude corresponding to that of a transmitting avalanche transceiver at a distance of approx. 40 m.

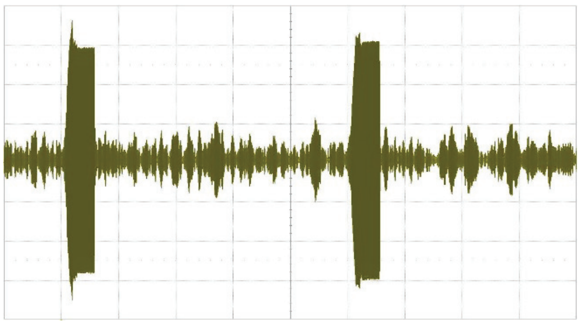

Figure 7: PULSE Barryvox signal when a buried avalanche transceiver is present, note that the amplitude of the noise between the "beep sounds" remains on an equally low level as shown in Figure 6. The difference between "signal" and "noise" is very distinct.

Figure 8 shows that a Tetra radio in standby mode is not influencing the receiving avalanche transceiver when holding them 30 cm apart.

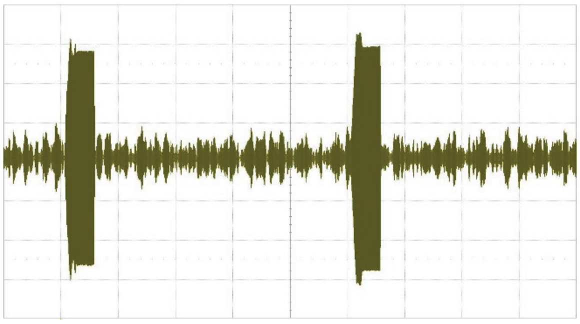

Figure 8: Interfering object: Tetra radio in standby mode at a distance of 30 cm from the avalanche transceiver

Figure 9 shows the influence of holding a Tetra radio in standby mode 15 cm apart from the receiving avalanche transceiver. The noise level between the “beep" tones dramatically increased in amplitude, making the difference between “signal” and “noise” much less distinct. This difference is known as the “signal to noise ratio” SNR, which is a critical value for the reliability of signal detection.

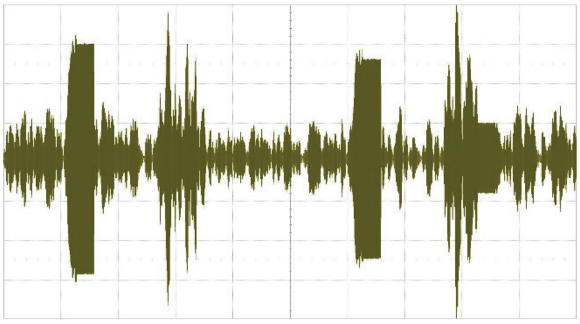

Figure 9: Interfering object: Tetra radio in standby mode at a distance of 15 cm from the avalanche transceiver

Figures 10 and 11 show the influence of a Tetra radio in transmit mode 30 cm and 15 cm apart from the receiving avalanche transceiver.

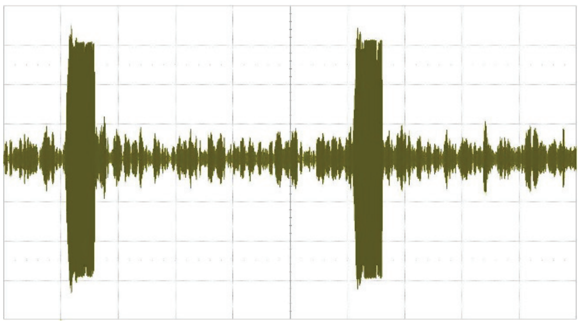

Figure 10: Interfering object: Tetra radio in transmit mode at a distance of 30 cm from the avalanche transceiver

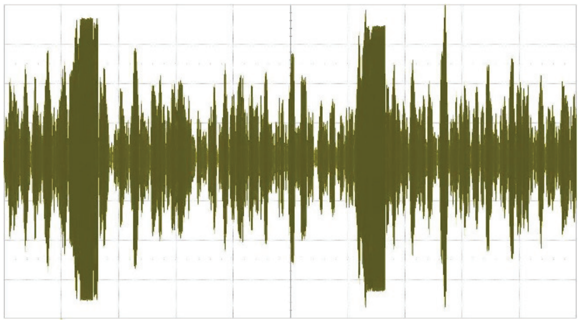

Figure 11: Interfering object: Tetra radio in transmit mode at a distanceof 15 cm from the avalanche transceiver

It is clearly visible that at distances closer than 30 cm the interference from a radio transceiver increases drastically in standby mode (Fig. 9) but most notably in transmit mode (Fig. 11).

The interference caused by a radio transmitter with a constant amplitude such as an FDMA radio is considerably lower than the interference caused by a TDMA radio with pulsed amplitude and may vary between different brands and models of communication equipment.

In general: the interfering impact of a radio transceiver depends heavily on the channel access mode (FDMA or TDMA) and not on analog or digital operating mode of the communication equipment.

4.2.1 Signal search without an applied H-field signal

FDMA radio: all of the tested avalanche transceivers show no false detection with a transmitting FM radio at a distance of 30 cm. But three of them showed sporadic unwanted signal detection (ghost signals) when the FM radio was switched from receive to transmit mode at a distance below 40 cm.

TDMA radio: only 3 out of 9 tested avalanche transceivers showed no false detections with a Tetra radio in transmit mode at a distance of 30 cm.

Four of the tested avalanche transceivers showed sporadic false detections, two models at a distance below 40 cm and another two models at a distance of less than 1 m.

Two of the tested avalanche transceivers where seriously disturbed by holding a Tetra radio in transmit mode about 1 meter apart from the receiving avalanche transceiver.

In this case the amount of false detections of the affected avalanche transceiver rises dramatically which renders a reliable search for buried subjects nearly impossible for the rescuer.

4.2.2 Signal search with an applied H-field signal

FDMA radio: 1 out of 9 avalanche transceivers showed signal loss, another one showed false detection of distance and direction (both with a UHF FM radio).

TDMA radios: for 7 out of the 9 tested avalanche transceivers false detection of distance or direction indication has been observed at a distance below 40 cm and for two of them at a distance below 50 cm. The reported observation was only visible or reproducible for one out of the two tested Tetra radio models (Tab. 3).

Also in this test there were two avalanche transceivers, the same ones as in chapter 4.2.1, which were heavily disturbed by holding a Tetra radio in transmit mode approx. 1 meter apart from the receiving avalanche transceiver. This lead into the same conclusion as described in chapter 4.2.1.

Based on the results it became obvious that the interfering impact of radio transceivers in combination with avalanche transceivers is different between FDMA and TDMA radios.

5 CONCLUSIONS

As a matter of principle and to avoid running into interference issues, most of the avalanche transceiver manufacturers have published proprietary recommendations for handling interfering objects (e.g. radios, mobile phones, headlamps), metallic items (pocket knives, magnetic buttons), or other avalanche transceivers close to an avalanche transceiver in avalanche terrain.

And as already reported by Meister and Dammert (2014), there is not a single general recommendation for “SEND” as well as “SEARCH” mode. Therefore, best practice for avalanche transceiver users would be to consult the manufacturer’s instructions.

„SEND“ Mode

The results of the measurements show that in “SEND” mode influence has to be expected at distances lower than 10 cm from the avalanche transceiver. Therefore, and based on the results from Meister and Dammert (2014), we recommend to keep a minimum distance of 20 cm to the avalanche transceiver in “SEND” mode.

„SEARCH“ Mode

Based on the results and on the variety of different frequency bands for communication equipment it is not possible to make a single recommendation in terms of minimum distance for “SEARCH” mode.

As a general recommendation for a search, keep the avalanche transceiver at least 50 cm away from any communication equipment.

5.1 Best practice to verify interfering objects in “Search” Mode (a simple field test)

First test: place the avalanche transceiver in an interference-free environment without any sending device. Switch the avalanche transceiver to “SEARCH” and hold the radio transceiver at a distance of 1.0 m to the avalanche transceiver. Keep the radio transceiver in transmit mode and move it slowly towards the avalanche transceiver down to about 50 cm, depending on the specific recommendation of the avalanche transceiver manufacturer. Then slowly change the orientation of the radio transceiver relative to the avalanche transceiver around all three axes. The avalanche transceiver must remain in signal search. Any coarse search indication is caused by interference from the radio transceiver.

Second test: place the avalanche transceiver to be tested in an interference-free environment with an additional avalanche transceiver to generate a signal. Place the additional avalanche transceiver so far apart that the receiving avalanche transceiver to be tested indicates approx. 40 on the display. While doing the same test as described in the section “First test” with the radio transceiver observe the indicated signal at the avalanche transceiver. If the indicated distance and/or the direction gets unusable for locating the transmitting avalanche transceiver, the interference from the radio transceiver is too strong.

In both tests observe the distances and directions indicated and note the resulting influence on an avalanche rescue search.

Small influences can be handled by the rescuer, but strong influences would render a avalanche transceiver search impossible.

Remark: the outlined test procedure can be applied to checking the influence of any electronic equipment.

Finally, be aware of the influence on the search strip width by interference. Even if an avalanche transceiver is not indicating any signals caused by interference, the search strip with may be reduced. An avalanche transceiver with analog tone support can help to recognize interference.

6 ACKNOWLEDGEMENTS

The authors would like to thank the following individuals and companies for their corrections, linguistic review and provision of radio test devices for this paper:

Harald Remmele, Sepura Deutschland GmbH, Deutschland
Jetmir Rexhepallari, Lixnet AG (Motorola), Schweiz, in cooperation with Zermatt Bergbahnen AG
Theo Maurer, Alpine Rettung Schweiz
Felix Meier

FUTURE PERSPECTIVE

In the future the use of TDMA based radio transceivers will become more and more commonplace for rescue organizations and professional operations. Users of such communication equipment should be aware of the interfering impact of TDMA based radio transceivers on receiving avalanche transceivers during a search.

CONFLICT OF INTEREST

Two authors of this paper are employees of CCS Adaxys AG and are involved in the development of avalanche transceivers.

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