# KNOW YOUR ENEMY. KNOW YOUR TECHNOLOGY – A PROCESS-ORIENTED APPROACH TO MITIGATING INTERFERENCE EFFECTS DURING AVALANCHE RESCUE

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ABSTRACT: Electromagnetic interference can complicate avalanche rescue searches by reducing receiving range or causing unstable indications. Potential sources of interference include personal electronic devices, metallic and magnetic objects, electrical or electronic infrastructure, and atmospheric electrical activity. Their effects depend, among other factors, on the specific combination of avalanche transceiver and interfering source, the distance, and the operating mode. This paper considers interference separately for transmit and search mode and combines published studies with qualitative internal observations and practical measurements. The 20 cm recommendation in transmit mode and the 50 cm recommendation in search mode are discussed as important practical guidelines. In particular, practical implementation in search mode shows that this recommendation alone does not guarantee interference-free searching. The paper focuses on a conceptual six-step process. It is intended to support advanced users and professional organizations in considering potential interference during preparation, detecting it during a search, and adapting their procedures to the specific device.

KEYWORDS: Avalanche rescue, avalanche transceiver, electromagnetic interference

## 1. INTRODUCTION

Avalanche transceivers are a key tool in companion and organized avalanche rescue. During a search, they must detect signals from buried persons as early and reliably as possible and process them into distance and direction information for the searching person. This function can be impaired by external sources of interference. Published studies and practical field tests describe, among other effects, reduced reception range, unstable guidance, and false-positive or so-called ghost signals.

Potential sources of interference include electronic, magnetic, and metallic objects and infrastructure, as well as atmospheric electrical activity. The interference situation differs fundamentally between transmit and search mode. In transmit mode, the main concern is the potential passive influence of metallic or magnetic components in the immediate vicinity of the avalanche transceiver on the transmitted signal. In search mode, the avalanche transceiver operates as a sensitive receiver. Active electronic sources of interference can then impair device performance.

The common recommendation of a minimum distance of 20 cm in transmit mode and 50 cm in search mode represents an established practical guideline. In transmit mode, it can generally prevent relevant passive interference in the immediate vicinity. In search mode, however, the recommended distance cannot always be maintained reliably during a dynamic search. In addition, individual sources of interference may require greater distances (Forrer et al., 2018). The 50 cm recommendation should therefore be understood as an important part of interference management, but it is not sufficient on its own in every situation.

This paper combines published studies and recommendations with qualitative internal observations and practice-related measurements. On this basis, a six-step process for advanced users and professional organizations is derived. It is intended as a conceptual model and has not been empirically validated.

## 2. TECHNICAL BACKGROUND

### *2.1 Avalanche transceiver signal and operating modes*

Avalanche transceivers operate with a standardized electromagnetic signal at 457 kHz. In transmit mode, the device generates regularly recurring signal pulses intended to be detected by other avalanche transceivers. In search mode, the device receives the signals of one or more transmitters and derives, among other information, direction and distance indications. The exact signal processing is

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device- and manufacturer-specific; for the purposes of this paper, however, it is essential that the searching device must also detect weak signals at greater distances.

This high receiver sensitivity is required to achieve the greatest possible search range and stable search performance. At the same time, it can allow electromagnetic influences from the surroundings to affect signal detection and digital processing. The technical requirements for signal transmission and the permissible signal parameters are defined in the ETSI EN 300 718 series of standards.

## *2.2 Passive and active interference*

For practical classification, a distinction is made between passive and active interference. These terms describe different mechanisms, although both may occur simultaneously in a specific situation.

*Passive interference*

Passive interference originates from metallic and magnetic objects or components. These can alter the electromagnetic circuitry of the avalanche transceiver. In the immediate vicinity of the transmitter, for example, they can detune the transmitting circuit or influence the radiated field. As a result, the effective transmit power or the signal range may be reduced. Passive impairment can also occur in search mode, for example through detuning of the receiving circuit.

Potential passive sources of interference include, for example, metal parts and magnets on clothing and equipment, metal-containing packaging (such as muesli bars, energy gels or eyeglass cleaning cloths etc.), carabiners and ice screws. Electronic devices can also act as passive sources of interference, regardless of whether they are switched off or on. In this context, the relevant factors are not the device's energy consumption but the nature of its metallic or magnetic components.

According to the studies available, relevant passive interference of body-worn equipment in both transmit and search mode occurs only in the immediate vicinity, at distances of less than 3 cm (Meister and Dammert, 2014). Big passive objects or infrastructure like fencing, water pipes or other conductive materials can cause deterioration of the transmitting signal distances up to many meters.

*Active interference*

Active interference is caused by electrical or electromagnetic processes in an operating electronic or electrical source. Examples include voltage regulation, display control, or other internal device processes. The resulting interference components can couple into the sensitive receiving path of an avalanche transceiver and impair the search.

Potential active mobile sources of interference include, for example, smartphones, radios, digital watches and wristbands, smart rings, (action-) cameras, GPS and satellite communication devices, headlamps, power banks, heated clothing, heated gloves, heated insoles, electronic avalanche airbags and snowmobiles.

In addition, permanently installed or large-area infrastructure such as lift systems, power lines, ground cables, snowmaking machines, transmission masts and other current-carrying infrastructure can affect the search.

The specific effect cannot be reliably derived from the device category alone. It depends, among other factors, on the operating mode of the avalanche transceiver, the distance and spatial arrangement, the operating state of the source of interference and its technical design. The state of charge and temperature can also influence the interference behavior of individual electronic devices.

In the event of approaching thunderstorms or indications of increased atmospheric electrical activity, possible interference from atmospheric electric fields or discharges should also be considered as an external source of interference.

A basic prerequisite for active interference is that part of the usually broadband interference falls within the 457 kHz frequency spectrum. The higher the energy consumption of a source of interference, the more likely it is to have interference potential.

Another important factor is the distance from the avalanche transceiver. The possible interference effect decreases approximately with the third power of the distance. Halving the distance therefore results in an interference effect that is approximately eight times stronger.

### *2.3 Mobile versus infrastructural sources of interference*

For practical assessment, it is useful to distinguish between permanently installed infrastructural sources of interference and mobile sources of interference.

*Mobile sources of interference*

Mobile sources of interference or sources carried close to the body can be managed through suitable carrying positions, sufficient distance, handover to a non-searching person, or switching off the device. It must be considered that mobile objects can cause active electromagnetic interference when switched on and can remain passively relevant when switched off because of their metallic or magnetic components.

*Infrastructural sources of interference*

Infrastructural sources can cause interference from a considerable distance. They generally cannot be controlled, and a searching person usually cannot freely choose the distance from them. The specific range and strength of possible interference cannot be reliably derived from the type of infrastructure alone. The same applies to effects caused by increased atmospheric electrical activity.

## 3. INTERFERENCE IN TRANSMIT MODE

### *3.1 Interference in transmit mode*

In transmit mode, metallic and magnetic objects in the immediate vicinity of the avalanche transceiver are of particular concern. One possible interference effect in transmit mode is attenuation of the radiated transmit signal. This can reduce the usable reception range for the searching person, which may result in a reduced covered search strip width and consequently a loss of time. Within the remaining range, however, the signal can typically still be received stably.

### *3.2 Preventive warning function of modern avalanche transceivers*

Modern avalanche transceivers can detect possible impairment of the transmit function and alert the user. Depending on the device, the warning may be visual, acoustic, or displayed on the screen. The specific implementation and sensitivity of the warning function depend on the device and software.

The warning is intended to prompt the user to identify the possible source of interference and increase the distance from the avalanche transceiver. If necessary, the source of interference should be removed, switched off, or repositioned. A clearly perceptible and understandable warning function can therefore be classified as useful preventive behavioral feedback. It can help prevent relevant impairment of the transmit function from occurring in the first place.

### *3.3 Technical compensation as a fallback solution*

In certain modern avalanche transceivers, possible impairment of the transmitting circuit can be technically compensated. The device may attempt to readjust the operating parameters of the transmitting circuit or the transmit power. The aim is to limit the effects of an unfavorable proximity to a source of interference.

The specific technical implementation depends on the device and software. Such compensation does not eliminate the source of interference, however. It should therefore be regarded as a technical fallback solution and not as the primary measure.

For individual devices, increased energy consumption due to technical readjustment has been documented. The additional energy requirement may depend on the device model, the extent of the required readjustment, the operating state, and the duration of the interference.

### *3.4 Significance of the 20 cm recommendation*

The recommendation to maintain a distance of at least 20 cm from potential sources of interference in transmit mode remains an important practical guideline. The external and internal findings available describe relevant passive interference primarily in the immediate vicinity, at distances of approximately 3 cm. The 20 cm recommendation is therefore well above this observed near-field range and provides a practical distance buffer.

This buffer takes into account possible changes in position while carrying the equipment, changing body positions, movement of equipment, and possible changes in the positions of the avalanche transceiver and the source of interference in an avalanche.

# 4. INTERFERENCE IN SEARCH MODE

## *4.1 Interference in search mode*

Compared with transmit mode, search mode represents a more complex and practically more critical interference situation. In search mode, particular attention should be paid to active electronic devices and potential interference from infrastructure.

An active source of interference can generate additional background noise or individual interference pulses. This can worsen the signal-to-noise ratio: the useful signal from a buried transmitter may be detected later, tracked less reliably, or not clearly classified as an avalanche transceiver signal by the signal processing. This can lead to misleading or delayed direction, distance, and transmitter-number indications. Under certain circumstances, the searching device may no longer be able to cover the standard recommended search strip width reliably. As a result, there is a risk that buried persons will not be found or will be found only after a delay.

Periodic or pulse-like interference can be interpreted by the signal processing as a possible avalanche transceiver signal. This can produce false-positive or so-called ghost signals that indicate a transmitted signal even though no corresponding transmitter is present. In areas without buried persons, this can cost valuable search time. In avalanches without any buried persons, the rescuers' exposure to the risk of subsequent avalanches may also be prolonged.

Reduced range and ghost signals are not mutually exclusive; they can occur with the same source of interference or during different phases of a search.

Active interference requires the relevant electronic or electrical source to be operating. When the source is switched off, this active interference as an operating cause is eliminated. Metallic or magnetic components of the device may nevertheless continue to cause passive interference, although the effective range of this influence is substantially reduced, to less than 3 cm.

It should be verified whether electronic devices can actually be powered down completely or whether they can only be placed in standby mode, in which they remain electrically active and may continue to cause interference. If supported by the device, the analog audio mode can be used for this verification during preparation.

## *4.2 Significance of the 50 cm recommendation*

The recommendation to maintain a distance of at least 50 cm from active electronic sources of interference in search mode remains a reasonable practical minimum recommendation. It reduces the probability of relevant active interference but does not constitute a physically sharp boundary or a guarantee of interference-free operation. Individual sources of interference, particularly certain digital radios, may remain relevant at greater distances (Forrer et al., 2018).

Studies by the Safety Research of the German Alpine Club (DAV) demonstrate the practical relevance of electronics carried close to the body. In the tests presented there, smartphones at a distance of 25 cm from avalanche transceivers resulted in substantially reduced reception range in some cases, and locating the transmitter was sometimes associated with signal dropouts. (Berker and Fritz, 2024). In an earlier study, the devices under test exhibited isolated minor interference effects at a distance of 40 cm, with more pronounced effects at distances of 30 cm or less (Barkhausen, 2012).

These test results demonstrate that the 50 cm recommendation provides a smaller practical distance buffer in search mode.

## *4.3 Infrastructure and atmosphere as potential sources of interference*

Not all sources of interference are carried by the searching person. Infrastructure and atmospheric phenomena can affect a search from a considerable distance. Possible interference must therefore also be considered when personal electronics have already been removed or switched off.

### *4.4 Detection and communication of interference*

Modern avalanche transceivers can detect increased interference levels or specific interference patterns and alert the user to possible interference through warnings, an adjusted search strip width, or other indications. The specific detection and communication functions depend on the device and software.

Interference may already be present without the avalanche transceiver issuing a warning. Depending on the device, a warning may be triggered only when the interference level or the intensity of an interference pattern exceeds a device- and software-dependent threshold, or when the signal processing classifies the situation as external interference according to defined criteria. A gray area may therefore exist between interference that is present but not yet indicated and interference that is clearly communicated. The absence of a warning does not reliably rule out a relevant reduction in search performance.

For advanced users, analog search audio may therefore be helpful if the respective avalanche transceiver provides this function and the user has been trained in its use. Increased or altered background noise in the audio output may indicate external interference. Where appropriate, consequences for the further search strategy can be derived from this.

## 5. PRACTICAL IMPLEMENTATION OF THE DISTANCE RECOMMENDATIONS

The 20 cm recommendation in transmit mode and the 50 cm recommendation in search mode are valuable as minimum distances that are easy to communicate in practice. Their implementation in the field, however, depends not only on the technical performance of the avalanche transceiver. It is also crucial whether the spatial separation between the avalanche transceiver and a possible source of interference can actually be maintained throughout the activity.

In transmit mode, the recommended distance can usually be taken into account during preparation by appropriately positioning the avalanche transceiver and the remaining equipment. In search mode, however, the spatial relationship changes continuously. Maintaining a minimum distance should therefore not be understood as a one-time measure but as a recurring task during the search.

### *5.1 Dynamic search*

An avalanche rescue search does not take place under static laboratory conditions. The searching person moves over uneven terrain, changes body position, and repeatedly approaches potential sources of interference or moves away from them. As a result, the distance between the avalanche transceiver and the source of interference can change considerably within a short time without this being consciously perceived.

Situations are particularly relevant in which the avalanche transceiver is held in front of the body while electronic devices are carried on the torso, in the hands, or in a trouser pocket. Raising a leg or changing the hand holding the device can alter the spatial arrangement. A position that appears sufficient when standing upright may therefore not provide the same distance in every body position.

The 50 cm recommendation should be understood as a reference for planning and as guidance during the ongoing search. In the field, it cannot be checked with a measuring tape in every situation. Carrying positions must therefore be selected so that sufficient distance remains plausible not only in theory but also under dynamic conditions.

### *5.2 Smartphone carrying positions*

The carrying position of a smartphone can be decisive in determining whether the 50 cm recommendation can be achieved in practice in search mode. With many common carrying positions, the distance from the avalanche transceiver held in front of the body can be significantly less than 50 cm. A smartphone in a suitable backpack compartment, by contrast, can allow a greater and more consistent distance. Carrying the smartphone in the trouser pocket on the side of the body facing away from the avalanche transceiver can support compliance with the recommended distance if the device is held consistently. The trouser pocket on the side facing the avalanche transceiver should be regarded as less suitable because the distance changes with leg movement.

This classification is not a general statement about every person or every individual equipment combination. It does, however, show that the question “Where is the smartphone carried?” is more useful for assessing interference than simply confirming that a smartphone is present.

Preparation for a search should therefore record not only which electronic devices are carried. It should also specify where they will be carried during a search and whether that carrying position is compatible with the intended handling of the avalanche transceiver.

### *5.3 Arm position*

Various training recommendations emphasize keeping the arm as extended as possible during the signal search and coarse search. This can increase the distance between the avalanche transceiver and the body and between the avalanche transceiver and electronic or metallic objects carried close to the body.

In user tests carried out by the author a few hours after theoretical training, it was observed that the extended-arm position was not performed consistently during a simulated search, even though it had previously been explicitly discussed.

This indicates that a technical recommendation alone is not sufficient if it is not transferred into a trained movement pattern.

### *5.4 Switching Off electronic devices*

Fully switching off an electronic device eliminates the active interference caused by its operation. From an avalanche-transceiver perspective, there are therefore strong arguments for switching off smartphones, radios, and other potential sources of interference carried close to the body before starting the search.

However, practical arguments also speak against recommending that all devices be switched off before every search. For example, switching off a smartphone and later switching it on again to make an emergency call can cause critical time loss under stress and unnecessarily complicate the coordination and search process.

### *5.5 Handing over electronic devices*

Personal electronic devices can also be handed over to another person. This is only a viable option if a non-searching rescuer is nearby and available. Depending on the amount of equipment and how it is carried, this may also take some time.

### *5.6 Practical consequence*

The 50 cm recommendation is technically understandable but cannot always be maintained reliably during a dynamic search. This does not mean that the recommendation is dispensable. Rather, it should be understood as a planning and behavioral rule supported by suitable carrying positions, trained movement patterns and switched-off or handed over devices.

## 6. PROCESS-ORIENTED APPROACH

The proposed process is intended for use by advanced users and professional organizations during avalanche rescue searches. It is a conceptual model and not an empirically validated standard procedure.

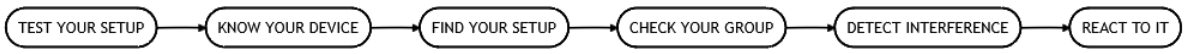



Figure 1: Six-step process to mitigate interference effects during avalanche rescue

### *6.1 TEST YOUR SETUP*

The user's own combination of avalanche transceiver and personal electronic equipment should be tested under realistic conditions, including carrying positions and simulated movement across avalanche debris. The following tests are recommended:

- signal-search test without a transmitter to observe ghost signals or interference indications on the transceiver;

- acoustic assessment of the sound level in analog mode;
- range test.

As a range test, a quick test based on the “realistic maximum range” according to ICAR AVA REC 0007 is recommended (International Commission for Alpine Rescue, 2008; Revision 2009). At the test location, the searching device is turned 45° to the left and 45° to the right from the coaxial coupling position, and directional accuracy is observed. The criteria are met if the direction indication points toward the transmitter within ±30° for 80% of the time.

The tests are intended to familiarize users with their own setup and are particularly useful in connection with fleet equipment, for example a uniform radio type used by an organization. They cannot guarantee interference-free operation in an emergency.

In addition to these tests, training exercises and practical examinations should also be carried out under conditions that are as realistic as possible.

### *6.2 KNOW YOUR DEVICE*

Users should understand how their avalanche transceiver behaves in the presence of possible interference. In particular, they should assess:

- the nature and perceptibility of warnings under stress;
- possible adjustment of the displayed search strip width;
- the ability to distinguish a ghost signal from a real signal;
- acoustic behavior in analog mode.

### *6.3 FIND YOUR SETUP*

Based on the test results, the equipment used, and personal preferences, an individual tactic should be developed. This includes defining routine carrying positions for potential sources of interference for common activities. It should also be clarified in advance whether a defined arm and device position will be used during a search or whether the required distance will be ensured through other measures.

For every electronic device carried, it should be determined whether it will be temporarily switched off, removed, handed over, or moved to another carrying position during the avalanche transceiver search. Solutions for radio communication and emergency calls should preserve the required availability while minimizing interference with the avalanche transceiver. The selected tactic should be practically verified during training.

### *6.4 CHECK YOUR GROUP*

In addition to checking avalanche transceiver function, the group check should help identify and avoid critical equipment configurations. It should specifically cover what electronic equipment group members carry and where they carry it.

Routinely addressing this topic can also raise participants’ awareness of potential interference and the adjustments required during a search.

### *6.5 DETECT INTERFERENCE*

During the search, users should observe not only the actual avalanche transceiver signal but also the behavior of the device. Possible indications of interference include warnings, a reduced displayed search strip width, sudden changes in direction or distance indications, ghost signals, and signal losses.

Warnings support detection but do not necessarily capture every relevant instance of interference. If the device model provides this function, analog search audio can additionally be used to perceive changes in background noise. If ambient noise is sufficiently low and the user is familiar with the device and appropriately trained, analog tones may provide additional and, in some circumstances, more sensitive indications of interference.

### *6.6 REACT TO IT*

If interference is suspected, the following sequence is recommended:

- Check for body-worn sources of interference and increase the distance by repositioning the transceiver if necessary;
- hand over, remove, or switch off electronic devices that are not essential;
- check the device's visual and acoustic indications stabilize;
- if interference persists, consider infrastructure as a possible cause;
- reduce the search strip width during the signal search;
- reduce the search speed during the coarse search.

If the situation requires it and the device model permits it, the search strip width can be reduced manually. In extreme cases, micro-search strips approximately 3 to 5 m wide may be considered.

As an author opinion, a search speed of approximately 0.5 m/s is proposed as a reference value for the coarse search when device behavior is unstable. If necessary, the speed should be reduced further.

## 7. CONCLUSIONS

Interference can impair avalanche rescue searches through reduced range or false indications. The extent depends, among other factors, on the operating mode, the distance, and the specific combination of avalanche transceiver and source of interference.

The 20 cm recommendation in transmit mode is an effective and practical measure for generally avoiding relevant passive interference in the immediate vicinity. The 50 cm recommendation in search mode is an important practical guideline but not a guarantee of interference-free operation.

Effective management of interference requires an integrated approach. In addition to personal equipment, infrastructure, possible atmospheric influences, and device behavior must be taken into account. Warnings and atypical indications must be recognized, and the search strategy must be adapted to the specific capabilities and limitations of the device and to the trained procedure.

The proposed six-step process provides a practice-oriented framework for systematically considering interference during preparation, training, and search operations. Future studies should examine and further develop its practical applicability and effectiveness.

## 8. CONFLICT OF INTEREST

The author of this paper is an employee of ORTOVOX Sportartikel GmbH and is involved in the development of avalanche transceivers.

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