# MAKING AVALANCHE RESCUE EASIER AND FASTER BY ADDING SATELLITE NETWORKS TO THE EXISTING STANDARD

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ABSTRACT: Avalanche Tranceiver search is always very unprecise due to the given technology of the magnetic field which never can give an exact location. Search within this field and following the flux lines is for recreational users very difficult and in a worst-case scenario of an avalanche often impossible. By adding a dedicated GPS grid on the magnetic field of the buried person, the searcher does not have to follow the flux line but will be guided by the avalanche transceiver directly to the buried person. As connecting to all given satellite networks, the precision of the 3D finder is under 10 cm, the searcher does not have to do the time consuming out crossing and probing in the end of the search. The user, searching the victim, just must follow very easily the arrow on the display.

The research and development were made together with leading mountain rescue organizations and the German Fraunhofer institute. Field-test show, that the time for the complete search can be reduces by 30% in average.

The 3D finder has a dedicated expert mode for professionals with special functions for multi burials situations, deep burials, revert to send and many more.

KEYWORDS: Avalanche transceiver, GPS-Search, Faster.

## 1. BACKGROUND: THE EXISTING STANDARD

All avalanche transceivers currently on the market operate within a common technical standard that ensures interoperability between devices from different manufacturers. This standard specifies a carrier frequency of **457 kHz** and a transmission rate of **one pulse per second**, radiated through one, two, or three orthogonal antennas depending on the device class. Search is performed by measuring the strength and orientation of the resulting magnetic dipole field.

Because this standard underpins every certified device in use today, any new search technology must remain **100% backwards compatible**: a next-generation receiver must be able to locate any standard-compliant transmitter, regardless of brand or generation, and a next-generation transmitter must still be found by conventional receivers. Within this constraint, the objective of ongoing development is to reduce search time and cognitive load during what is, by definition, a high-stress, time-critical rescue scenario. Survival probability in avalanche burial drops sharply after the first 10–15 minutes due to asphyxiation, making even modest reductions in search time clinically meaningful.

The **3D finder**, developed by nivia, introduces a fundamentally different search principle. Rather than requiring the rescuer to walk the characteristic curved magnetic field lines toward the transmitter — a technique that demands training and is prone to error under stress — the device allows the searcher to proceed in a direct, straight-line path toward the victim from the moment the first signal is acquired. At the end of the search, no signal-crossing or box-search maneuver is required: the receiver directly displays the calculated position of the buried person, independent of the transmitting device's brand, as long as it conforms to the 457 kHz standard. Probing is reduced to a confirmatory step that marks the exact excavation point before shoveling begins.

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## 2. CORE TECHNOLOGY: SENSOR FUSION OF MAGNETIC FIELD AND GNSS DATA

The patented mechanism underlying the 3D finder is a **real-time sensor-fusion process** that combines two independent sources of positional information: the magnetic dipole field emitted by the buried transceiver, and a dynamically constructed positioning grid derived from **Global Navigation Satellite System (GNSS)** signals. Neither data source alone is sufficient for a precise result — the magnetic field alone can only indicate *directional* trends toward the strongest pulse, and standalone GNSS positioning cannot "see" the buried transmitter at all. The innovation lies in cross-referencing both continuously as the rescuer moves.

### 2.1 *GNSS Grid Construction*

As soon as the 3D Finder detects the first pulses from a buried transmitter, it simultaneously initiates connections to the available GNSS constellations — GPS, GLONASS, Galileo, and BeiDou — all of which operate satellites in medium Earth orbit (MEO), not geostationary orbit, at altitudes of roughly 19,000–23,000 km. By combining signals from all four systems rather than relying on a single constellation, the device maximizes the number of visible satellites at any given moment, which is critical in the mountainous, often steep and shadowed terrain typical of avalanche terrain.

Using these multi-constellation ranging signals, the device constructs a dense virtual grid of several thousand candidate points overlaid on the physical search area surrounding the magnetic field source. Through triangulation (more precisely, multilateration) between the connected satellites, the measured magnetic field vector, and the receiver's own position, the system establishes an initial coordinate estimate. This is conceptually analogous to how a GPS car navigation unit fixes a position and then continuously refines it — except here, the "destination" is not a stored map coordinate but a live, magnetically detected transmitter.

### 2.2 *Iterative Probabilistic Refinement*

With every step the rescuer takes, and with every new pulse received (once per second, per the standard), the device re-evaluates the probability that each point in the GNSS grid corresponds to the true transmitter location. Points that remain consistent with both the decaying/strengthening magnetic signal and the satellite-derived motion vector are weighted more heavily; inconsistent points are discarded. As a result, the effective grid resolution — the "mesh size" — contracts progressively as the search proceeds:

- After approximately 3–4 pulses (roughly 3–4 seconds/steps into the search), the system produces a first fixed position estimate. At this early stage, both the magnetic field reading and the GNSS grid are still coarse, yielding a positional uncertainty on the order of 50–100 cm.
- After approximately 8–10 pulses, sufficient data has been fused to narrow the estimate to a radius of approximately 10 **cm** within the individually constructed local grid.

This progressive convergence is what allows the rescuer to simply follow a directional arrow on the display for the entire search, rather than actively interpreting field-line geometry. Once the calculated position radius falls within the resolution needed for excavation, the display switches from directional guidance to a probe prompt, indicating both the horizontal position and the estimated burial depth.

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### 2.3 *Continuous Cross-Validation with the Magnetic Field*

The GNSS grid does not operate independently of the magnetic measurement — the two are coupled at every processing cycle. As in conventional transceivers, the instantaneous signal strength of the 457 kHz pulse is measured; the 3D finder's contribution is to compare this magnetic reading, pulse by pulse, against the current state of the GNSS probability grid. This cross-validation step is what allows the system to assign a *quantified confidence value* to the buried device's estimated position, rather than relying on signal strength as a standalone (and inherently noisy) proxy for proximity.

### 2.4 *Signal Filtering: Kalman Filtering*

To separate reliable ("precise") readings from noisy or ambiguous ("uncertain") ones within the large volume of data generated by simultaneous GNSS and magnetic sampling, the system employs a **Kalman filter** — a recursive estimation algorithm widely used wherever noisy, high-frequency sensor data must be fused into a stable state estimate, including applications such as automotive navigation, aerospace guidance, meteorological modeling, and climate data assimilation.

In this implementation, the onboard processor uses the Kalman filter to continuously classify each point in the constructed grid as either a high-probability ("strong signal") or low-probability ("weak signal") candidate, updating this classification with every pulse (i.e., roughly once per second). By statistically weighting new measurements against the filter's running estimate of system state and noise, the algorithm can extract a stable position trend even from magnetic readings that would, on their own, be too weak or too noisy to interpret reliably — for instance, in cases of multiple burial, signal overlap, or unfavorable antenna orientation of the buried transmitter.

### 2.5 <u>Satellite Signal Acquisition Hardware</u>

Satellite signal reception is handled by a high-sensitivity multi-constellation antenna integrated into the top of the device housing. Beyond simply counting visible satellites, the onboard processor performs a qualitative selection: it prioritizes the satellites offering the strongest signal and most favorable geometric configuration (i.e., low dilution of precision), rather than treating all visible satellites equally. This selective weighting reduces the time required to establish an initial, usable grid and allows the system to begin fusing multiple independent position sources from the earliest phase of the search. Because the device draws on all four major GNSS constellations rather than a single one, reliable signal acquisition is achievable in the large majority of avalanche terrain, including steep north-facing slopes in the Northern Hemisphere (or south-facing slopes in the Southern Hemisphere) where sky visibility is comparatively restricted.

## 3. DEGRADED-MODE OPERATION: FALLBACK WITHOUT GNSS

In environments where satellite signals are unavailable or deliberately disturbed — for example, in regions subject to GNSS jamming — the 3D finder reverts to functioning as a conventional three-antenna magnetic-field receiver. Rather than leaving the user with an unguided signal-strength readout, the device automatically enters a **guided fine-search mode**: the display presents a directional crossing-pattern guide that walks the user through a structured fine search, culminating, as in GNSS-assisted mode, in a probing prompt.

Because the 3D finder's z-axis antenna uses a genuine ferrite core rather than a simplified coil design, positional accuracy in this fallback mode remains comparatively high even without satellite assistance: depending on burial depth, resulting precision is typically in the range of **10–30 cm** — narrower than what is achievable with conventional consumer-grade transceivers relying on magnetic field data alone.

## 4. OUTLOOK: TOWARD A REVISED STANDARD

Satellite-assisted search is likely to become an established category within avalanche safety technology rather than a transient feature. The device introduced for the 2026/27 season already represents a **second-generation implementation**. Through technology transfer from the parent company, Rosenberger Hochfrequenztechnik (Germany), an initial version of the satellite-fusion system was developed and brought to production readiness; rather than launching this first iteration, development proceeded directly to a refined second generation with improved stability and performance — a staged validation approach common in industries such as automotive electronics, where establishing quality benchmarks across an initial development cycle before market release is standard practice.

Looking further ahead, broader adoption of satellite-assisted search principles will likely prompt a review of the underlying 457 kHz transceiver standard itself. Any such revision would need to preserve full backwards compatibility, in keeping with the design philosophy underlying the 3D finder from its inception — but incremental technological advances of this kind will likely continue to shape how quickly, and how reliably, avalanche victims can be located.