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A deep insight into avalanche transceivers for optimizing rescue

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ABSTRACT

It is well known that in order to increase the chances of survival after an avalanche accident, the rescue time has to be minimized. Therefore, the accurate and prompt location of an avalanche victim is of vital importance. Nowadays, searching with avalanche transceivers is the only reliable method for locating a completely buried victim immediately after an accident. The present work is firstly focused on the magnetic field pattern generated by an avalanche transceiver and how it is perceived depending on the number of receiving antennas. The influence of the snow and soil media is theoretically studied. The computations show that the magnetic field is notably distorted by the soil at distances from the transmitter that can take place during the signal and coarse search. The location of the victim is usually directly inferred from the maximum signal position. However, the computations clearly show that this can be wrong. There is a location error limited to 50% of the burial depth for one and two-antenna receivers whereas for three-antenna transceivers, assuming location takes place within the third antenna range, this figure is reduced to 25% of the burial depth. Furthermore, real tests show that the cross-like search method using three-antenna receivers can be inefficient depending on the algorithm used for the distance calculation for burial depths greater than 1.5 m. As a result, a new search technique, called the bisector method, is proposed and experimentally validated. In addition, a new transmission mode mainly directed to minimize the location error is suggested. This is a vertical transmission that can optimize the search. The present theoretical and experimental outcomes will contribute to further progress in rescue operations conducted with avalanche transceivers.

1. Introduction

Snow avalanches claim scores of victims every year in mountainous areas, among local population, mountaineers, pilgrims, transportation and electrical power workers, military personnel and sportsmen.

It is not easy to obtain reliable figures but a good estimation may be an average of 200 people killed by avalanches every year. Working with data relating to sports men and women affected by avalanches in developed countries, Etter et al. (2004) estimated a total of 1593 deaths, during the period 1983/84 to 1992/93 and 1599 deaths in the following decade. Despite an increasing number of participants in outdoor winter sports, victim statistics remain stable with important temporary variations mainly due to local adverse snow and weather conditions (Jomelli et al., 2007).

International data are regularly presented in IKAR-CISA[1] reports, the best aggregated information on the issue. However, information on some countries, such as Spain, is not complete. Table 1 shows statistics according to the type of activity practiced by avalanche victims. In North America, avalanches are taking a growing toll on back-country skiers and snow-mobile users. In Europe, the highest rates of victims are back-country skiers followed by free ride-skiers and mountaineers. On the other hand, there is also a general downward trend of victims in controlled areas such as within the boundaries of ski resorts.

A number of papers published in several technical journals, usually preceded as communications in the Proceedings of the International Snow Science Workshop, present more detailed information on avalanche victims in given areas, usually in the Alpine arc or USA–Canada (e.g. Zweifel et al., 2012).

For obvious reasons, a significant number of these papers are devoted to the medical aspects of accidents (Brugger et al., 2001; Brugger et al., 2013; Falk et al., 1994; Haegeli et al., 2011). Burial time, burial depth and type of avalanche are important factors affecting the possibilities of recovering a victim alive. Burial time is the critical factor, as the probability of survival declines sharply after 8 min. Depth is also an important factor in rescue due to the increasing snow volume to be removed in addition to the difficulty of finding the victim. Data on the depth of burial of avalanche victims show only few cases of survivors buried at a depth of over 2 m (Tschirky et al., 2000).

Obviously, the victims of an avalanche must be rescued as soon as possible. The first people involved in the rescue are the companions of the buried subjects. Statistics presented by Slotta-Bachmayr (2005)

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[1] International Commission for Alpine Rescue.

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Table 1
Victims of snow avalanches according to activity (CISA-ICAR, 2010).

2*Season	Backcountry skiing	2*Freeride	On skirun	2*Alpinist	Snow-mobile	2*Other
2009/2010	93	37	2	39	24	17
2008/2009	69	44	3	19	38	23
2007/2008	68	25	3	24	24	12
2006/2007	60	21	0	21	11	7
2005/2006	77	59	2	18	14	22
2004/2005	95	41	2	25	7	14

show a significant survival decline if external rescue teams are involved due to the transportation time.

In addition to trained rescue dogs, the harmonic radar (RECCO) has been used by professional rescuers to locate buried victims. However, to date, avalanche rescue transceivers are the only technology that allows a fast and reliable search of completely buried victims by their companions (Genswein et al., 2009; Schweizer and Krüsi, 2003). The device can operate both as transmitter and receiver using solenoid antennas with ferrite cores as transceivers. For normal use, the avalanche transceiver generates a pulsed magnetic field of 457 kHz. Its specifications are regulated by the European standard *ETS 300718* (ETSI, 2001). If a victim is buried, another transceiver switched to the search mode can be used to detect and locate the signal of the victim's avalanche transceiver.

Many studies have demonstrated the usefulness of the device (Slotta-Bachmayr, 2005; Tschirky et al., 2000; Valt et al., 2009). Since the origin of avalanche rescue transceivers in the 1960s, a lot of work has been done by manufacturers resulting in yearly enhancements (e.g. digital transceivers, three antenna transceivers, multiple burial management, etc.). This work is normally protected by patents or more often by industrial secrecy, which can be considered a drawback for a faster development of this technology.

Associations such as CISA-IKAR, and single researchers have carried out the important task of testing and comparing the performance of commercial avalanche transceivers. Examples are works by Schweizer and Krüsi (2003) or Schreilechner et al. (2010). Some public research work has been done on avalanche transceiver technology. Michahelles et al. (2003) proposed to incorporate sensors to measure vital signs and environmental conditions to enhance avalanche transceiver search decisions. The processing of emitted signals has been studied in works such as Meier (2006) or Salós et al. (2007). In Matzner (2008) some functional aspects of modern transceivers were analyzed in order to design improvements.

Moreover, important work has been done on developing the best search strategies with standard avalanche transceivers. Currently, the basis of the search procedure is well established (searching for the first signal, following field flux lines and the final fine search). Researchers have attempted to bring greater depth to the classical method improving the search. For example, Genswein et al. (2009) proposed the optimization of the search strip width to minimize the search duration and Edgerly (2002) suggested a new fine search technique for solving deep burials. New search strategies based on the incorporation of a GPS receiver and new processing algorithms have also been proposed Piniés and Tardós (2006).

In contrast, there is a lack of studies concerning the core of the use of avalanche transceivers, that is the magnetic field generated by the transceiver and how it is perceived by the receiver. Lind and Smythe (1984) and Lind (1994) analyzed the avalanche transceiver performance taking into account the near field model and proposed some suggestion for modified use strategies. Ayuso et al. (2007) studied the distortions induced by the snow and the soil for any field component and source orientation.

The objective of this paper is to present the research undertaken by the Group of Technologies in hostile Environments (GTE) concerning this topic. We will show how the soil and the snow cover affect the field generated by the avalanche transceiver and its influence in the search phases. We also analyze how the magnetic field is perceived depending on the number of receiving antennas. The errors in positioning the victim will then be computed by the maximum signal offset. The theoretical work is supported by field tests. Finally, a new fine search method for modern digital transceivers with three antennas is proposed. In addition, a new transmission mode based on ensuring a vertical transmission is suggested. As a result, the search time and the localization error could be minimized. Consequently, a real increase in the survival chances of an avalanche victim could be achieved.

The paper is structured as follows. Section 2 reviews the fundamentals of the classical avalanche transceiver search. Section 3 studies theoretically the propagation of the magnetic field taking into account the effects of the snow cover and the soil for any orientation of the transmitter with respect to the air–snow–soil interfaces. Section 4 analyzes the location accuracy based on how the magnetic field is perceived by the avalanche transceiver. Corresponding field tests are presented in Section 5. Section 6 proposes different approaches for improving search

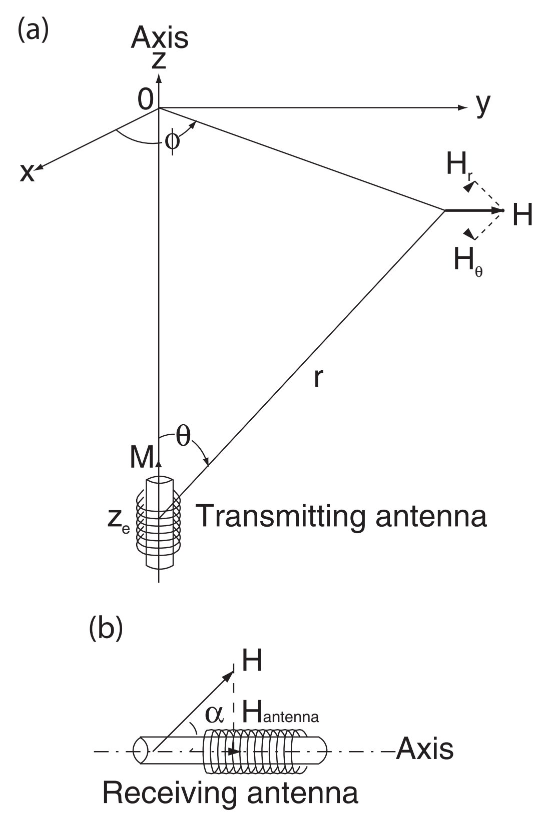

Fig. 1. (a): Magnetic dipole source and magnetic field components. (b): Sensed field ($H_{antenna}$) according to the relative orientation between the magnetic field and the axis of the receiving antenna.