# MEASURING THROUGH-THE-SNOW RADIOWAVE PROPAGATION OF LORA SIGNALS WITH TWO DIFFERENT SNOW PROFILES

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## Abstract

*Thanks to technological advancements in Search and Rescue (SaR) technology, trough-the-snow propagation of the LoRa protocol can foster operations. Herein, we report the raw data collected during a measurement campaign including a transmitting LoRa radio buried under the snow while the snow is completely profiled by nivologists. Preliminary data suggest that the wetter the snow, the more localized the signal attenuation around the transmitter is, even though the path loss is less affected by the snow type after about 20 meters.*

***Index Terms*** – Antenna Systems, Long-Range (LoRa), Path Loss, Radiowave Propagation, Search and Rescue.

## I. INTRODUCTION

In the latest years, significant research efforts have been devoted to improve Search and Rescue (SaR) operations [1], [2]. In this context, the LoRa technology has sparked interest for its characteristics that are highly promising for SaR [3]. Especially in mountainous environments, a wearable LoRa node could enhance the survival of avalanche victims thanks to the localization based on the signal's attenuation [4]. However, the radiowave propagation of the LoRa protocol when the transmitter is buried under the snow is still little investigated. In this contribution, we report, for the first time, raw data on the signal propagation when the transmitter (Tx) is buried under two different kinds of snow. Unlike previous works, the snow is completely characterized during the data collection by nivologists to understand its effects.

## II. EXPERIMENTAL SET-UP

The experimental set-up is shown in Fig. 1. A snowy plain at Col de Mez (GPS coordinates: 46°22'41" N, 11°49'33" E) free from obstacles was identified as measurement area. As hardware, LoRa T-beam boards (by LYLYGO) equipped with GSM/GPRS Antenna L722 (by LILYGO) are employed. The Rx (receivers) are inserted into IP 55 protective cases and are mounted on tripods. The Tx (transmitter), instead, is enclosed in a waterproof bag and then buried under approximately 50 cm of snow [4].

(a) (b) (c) (d)

**FIGURE 1** – (a) Plan of the terrestrial measurements over a satellite image of the measurement area. The measurement points nearer to the Tx than 10 m are not reported. (b) Measurement area on March 2024. (c) Vertically polarized LoRa radios during the calibration at 1 m of Tx-Rx terrestrial distance. (d) A nivologist during the snow characterization; the snow stratifications are clearly visible.

Each T-beam board is connected to a Raspberry Pi 4 to store the packets' characteristics (timestamp; received signal strength indicator, RSSI; signal-to-noise ratio, SNR). The Raspberry boards are synchronized through a Wi-Fi connection with a laptop. The transmission parameters of the employed "raw LoRa" protocol are the assessed values suitable for SaR from [4], except for the duty cycle, which was neglected to maximize the number of collected data. For each measuring point, the timestamps of the start and the end of the measurements are recorded. The ground distance between the measuring points was taken manually through a measuring tape. In this contribution, we focus only on the horizontal polarization and the burial depth of 50 cm.

## III. CONSIDERED SNOW PROFILES

Snow profiling was carried out by nivologists from AINEVA according to AINEVA's model 4, a technique adopting the taxonomy described in the standard ICSI-UCCS-IACS 2009. Snow Profile 1 was observed on the first day of measurements (March 7, 2024) and Snow Profile 2 was observed on the second day of measurements (April 11, 2024).

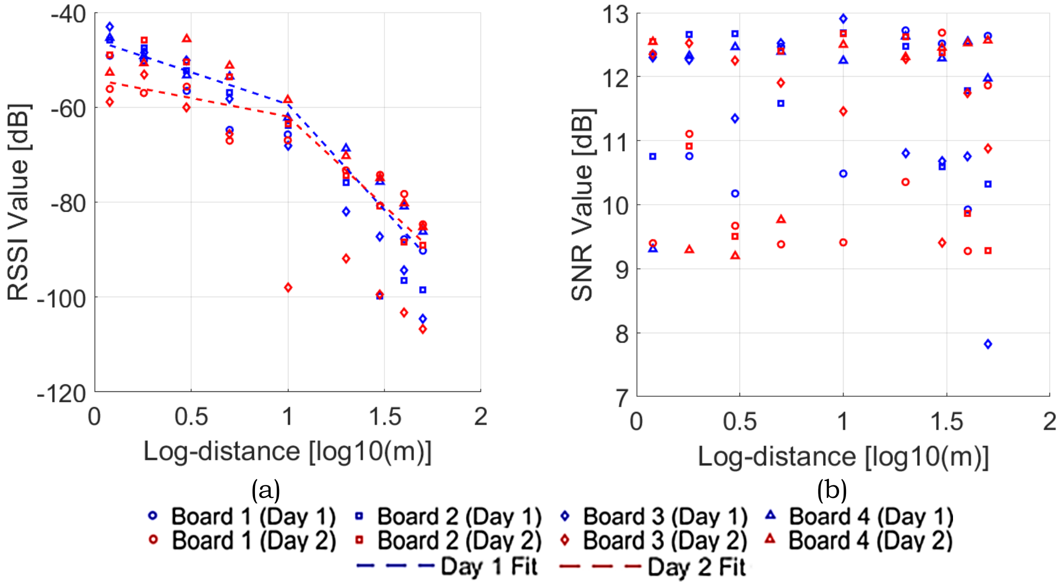
Snow profile 1 showed a total height of 116 cm, with significant internal warming and an almost isothermal temperature profile at approximately 0°C. The surface layer of the snowpack was dry with weak cohesion, featuring newly fallen precipitation crystals, while the layers below consisted of recently deposited snow, undergoing decomposition and some with rounded grains and a melt-freeze crust. The lower layers indicated a mix of wet and dry snow with higher densities, influenced by significant warming during the preceding month, February, which was one of the warmest on record.

The first half of April was also extremely warm, with temperatures +6.5°C above the 1991-2020 average, leading to accelerated snowmelt, further aided by the presence of Saharan dust which colored the surface snow red. Snow Profile 2 indicated a spring-like condition with an almost isothermal temperature distribution around 0°C, showing typical wet snow metamorphism with well-defined melt forms and a total snow height of 57 cm, including a top layer of fresh, moist snow. Below the surface, most layers consisted of rounded polycrystals and melt forms, with varying moisture levels and higher densities due to significant warming.

Overall, the two analyzed snow profiles are deeply different each other despite the relatively small temporal gap. From the electromagnetic perspective, it is clearly important that Snow Profile 2 is entirely made of wet snow (*forme fuse* in Italian); hence, a higher attenuation than Snow Profile 1 is expected along the whole ray path.

## IV. RSSI AND SNR DATA

The raw RSSI and SNR data measured during the two days (Day 1 March, Day 2 April) are reported in Fig. 2. Each point is averaged on about 300 LoRa packets (3 packets per second; 2 minutes per measurement point). Since the SNR is always much higher than 0 (Fig. 2b), it's impact on the path loss (PL) is negligible [4], and the path loss exponents (PLEs) can be retrieved by simply fitting the RSSI data even without computing the corresponding PL values. Indeed, the antenna's gains and losses will mostly affect the intercept value, which is qualitatively returned by the RSSI.



(a) (b)

**FIGURE 2** – (a) RSSI and (b) SNR data from the receivers during the two days.

The fit values summarized in Table I are fully coherent with the known mechanisms of short-range propagation, viz., *i*) PLE lower than 2 for closed-in propagation [5], *ii*) a breakpoint at the end of such closed-in propagation zone at about 10 m [5], [6], and *iii*) PLE comparable with urban obstructed radio links for distances longer than 10 m [4], [6]. Remarkably, according to the values in Table I, the attenuation of the signal seems to be localized around the transmitter for a wetter snow, but for d>20 m the path loss between the two days is very similar, suggesting that the effect is mostly local over the considered 50 m x 50 m area.

**TABLE I** – Values of the linear fits of the RSSI.

| Fit (Day, distance) | RSSI (1 m) | Path loss exponent |
|---|---|---|
| Day 1, d<10 m | -46 dB | 1.35 |
| Day 1, d>10 m | / | 4.45 |
| Day 2, d<10 m | -54 dB | 0.77 |
| Day 2, d>10 m | / | 3.77 |

## V. CONCLUSION

In this contribution, we reported preliminary data on the LoRa radiowave propagation in the SaR scenario of transmitter buried under the snow. For the first time, the electromagnetic data are reported together with complete snow profiles performed by nivologists. Currently, we are analyzing data including multiple burial depths, both horizontal and vertical polarization, and the use of aerial drones. Further details will be disclosed at the conference.

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