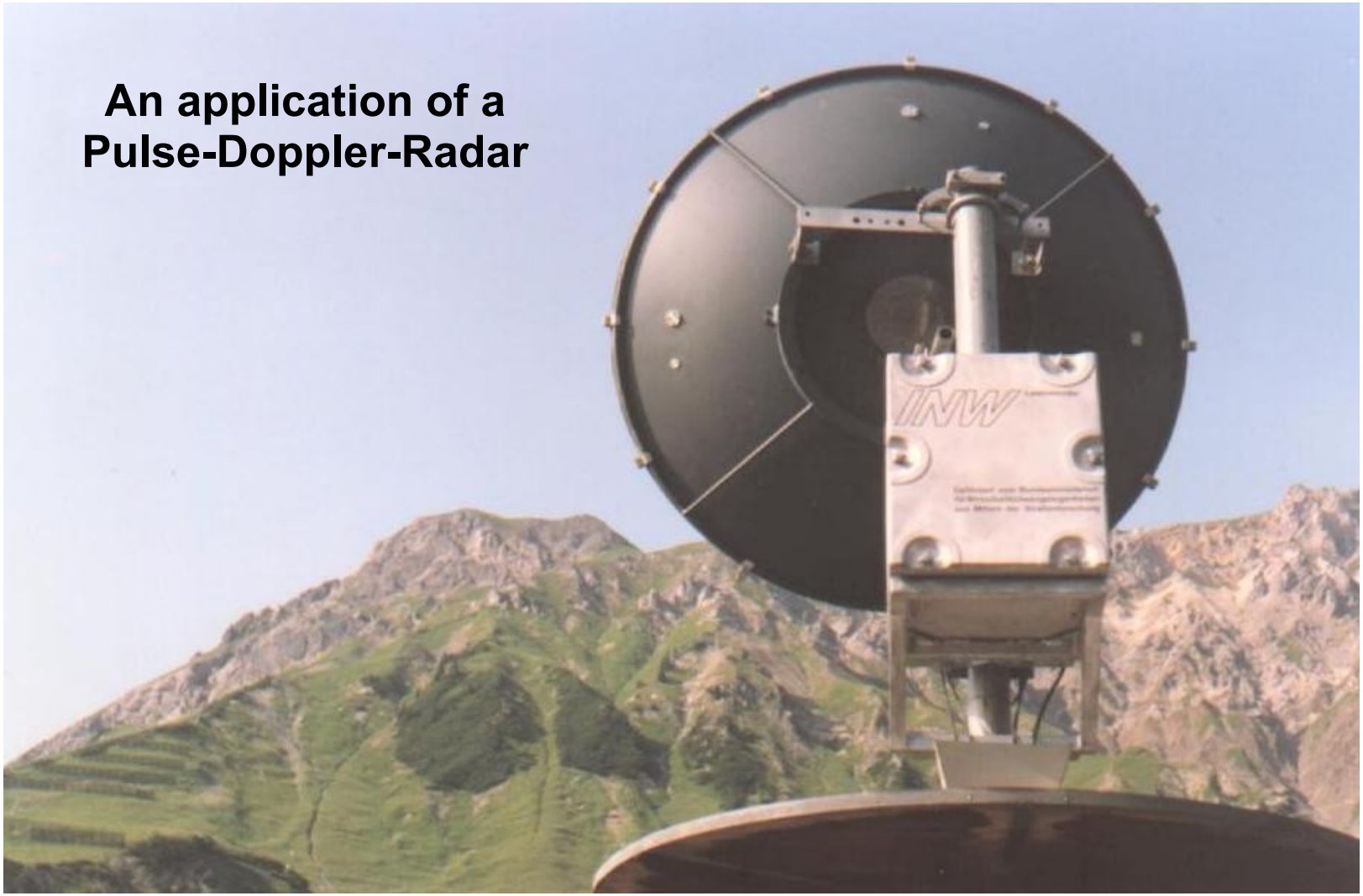
# Avalanche Radar „Multereck Avalanche Grimming“



# Outline

- **Introduction to radar systems**
  - Tasks of avalanche radar systems
  - Different radar technologies (CW-, FMCW-, Pulse-Doppler)
- **Pulse-Doppler Radar**
  - Principle of measurement
  - „Range Gating“
  - Velocity measurement
  - Data analysis
- **Pulse-Doppler Radar „Grimming“**

# Tasks

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- Measurement of dynamic properties of snow avalanches
- Road protection
  - Permanent surveillance of dangerous avalanche areas
  - Early detection of avalanche events
- Verification of artificial triggered avalanches

# Radar Overview

## Different radar technologies

- Continuous wave (CW-) radar
  - good for velocity measurements
  - no range discrimination
- Frequency modulated CW (FMCW-) radar
  - range and velocity measurements possible
  - difficult signal processing
- Pulse-Doppler radar
  - range discrimination (“range-gating”)
  - velocity measurement (Doppler-effect)

# Pulse-Doppler Radar

## Types of measurement

- Position of target - echo delay
- Velocity of target - echo doppler frequency shift
- Reflectivity (“size“) of target - intensity of echo signal

# Pulse-Doppler Radar

## Principle of measurement

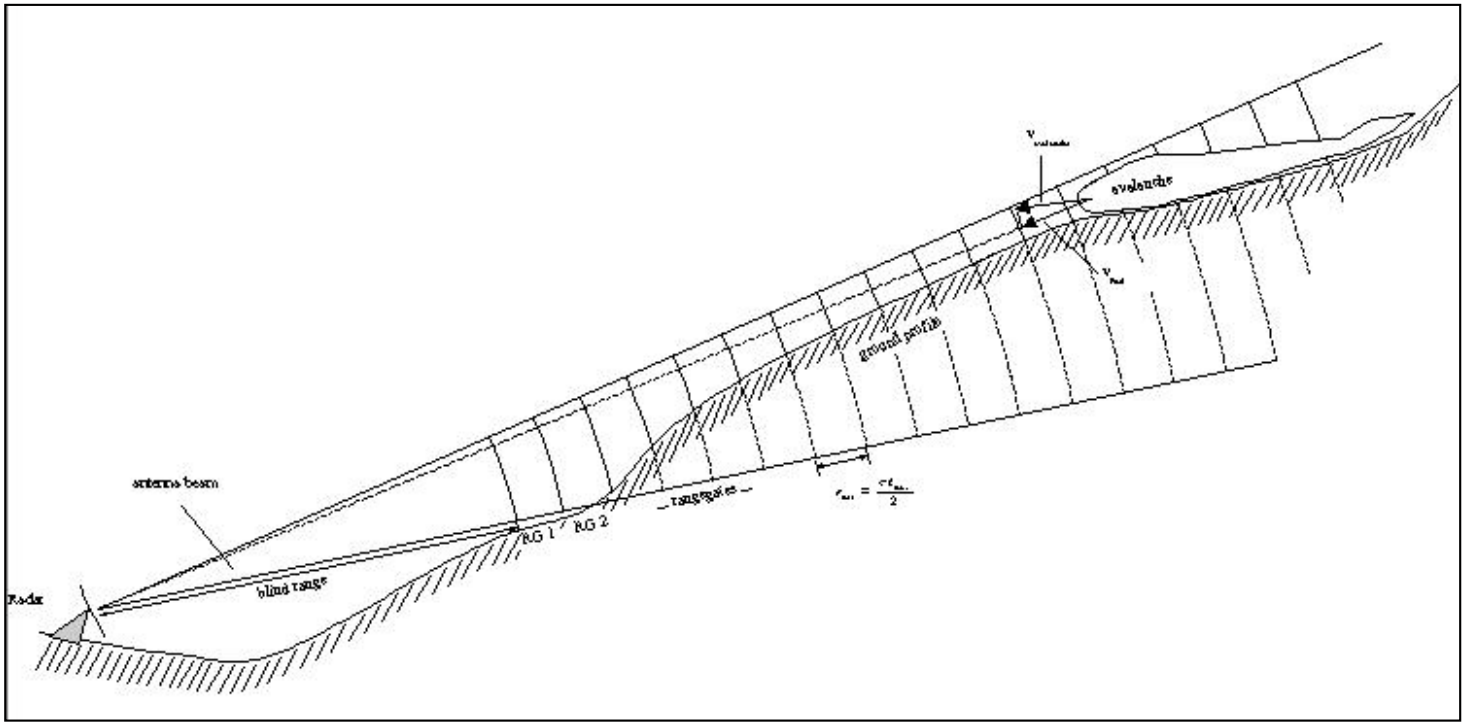
- Transmission of a series of short microwave pulses
  - Pulse length is 1/3 μs, pulse repetition frequency (PRF) is 25 kHz
- Used microwave frequency
  - C-Band : between 5 - 6 GHz minimizes attenuation
- Reception of echoes reflected by moving snow
- Evaluation of the echo signals

# Radar Principle

## Range Discrimination “Range-gating“

Large target area ⇒ continuous echo instead of pulse echoes

Sampling of the echo depends on the pulse length (every 1/3 μs = 50m)



# Radar Principle

## Velocity measurement

- Doppler frequency shift
  - frequency of the reflected signal is shifted against the frequency of the transmitted pulse if the target is moving
- Doppler shift of the received signal‘s frequency
  - about 37 Hz / 1 m/s
- Resolution of 0.6 m/s, maximum of 90 m/s
  - because of the 4 times oversampling

$$f_{Dmax} = \frac{f_{samp}}{2} = \frac{f_{prf}}{2}$$

$$\Delta f = 2\frac{v_{rad}}{c} f_0$$

$\Delta f$ … Doppler frequency shift

$v_{rad}$ … Radial velocity of the target

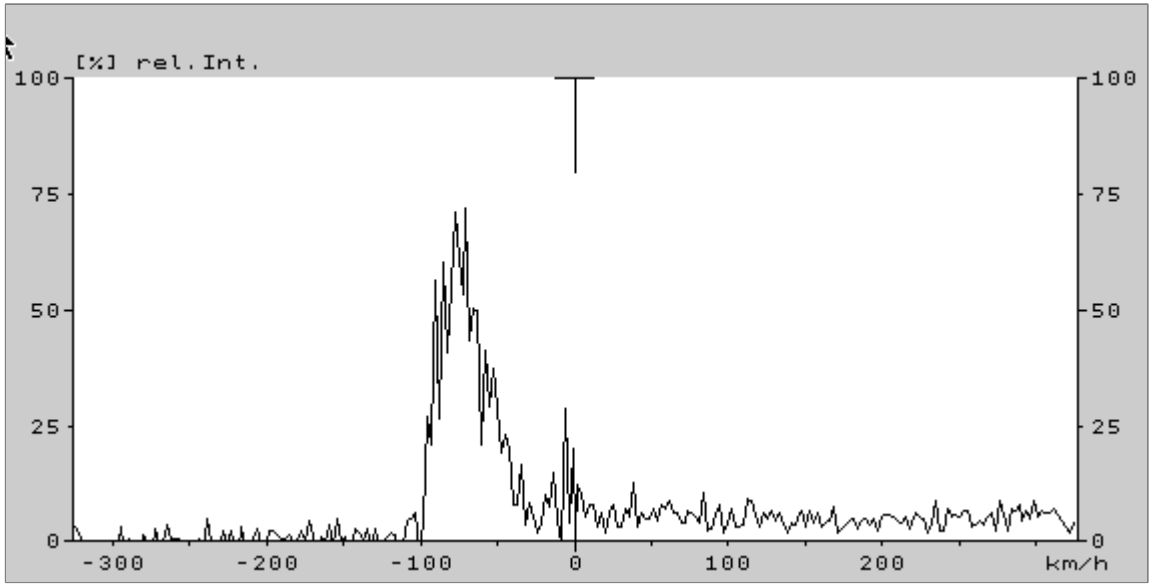
$c$ … Velocity of light

$f_0$ … Frequency of the transmitted signal

# Radar Principle

## Velocity measurement

- Doppler- or Velocity Spectrum
  - A moving object like an avalanche produces a continuous spectrum
  - Discrimination between positive and negative velocities possible



# Radar Principle

## Echo Intensity

- The maximum of the spectral intensity identifies the velocity of the avalanche front since it has the largest radar cross section.

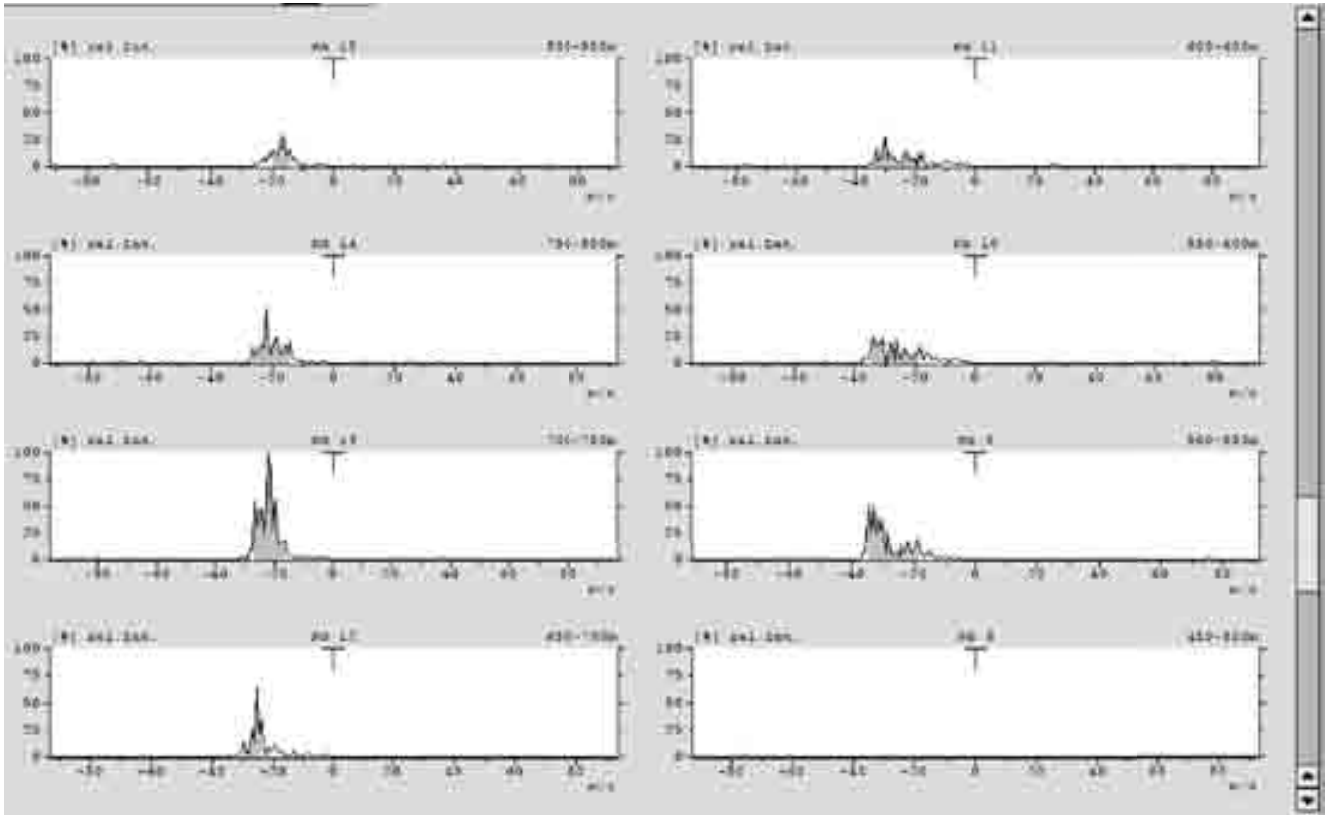
- The overall echo power (integral of the whole spectrum) could lead to information about the size of the avalanche

  – Density of the snow in the avalanche
  – Reflectivity of the snow in the avalanche

# Data Display

## Display

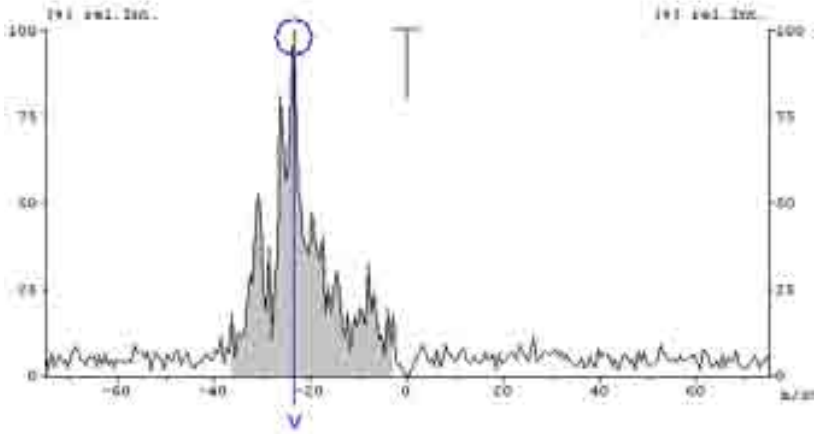
- Spectra View



# Data Display

## Data Analysis

- Velocity Spectrum
  - Velocity @ max. intensity
  - Maximum velocity
  - Average velocity / standard deviation
- Time Response
  - Velocity @ max. intensity
  - Spectrogram



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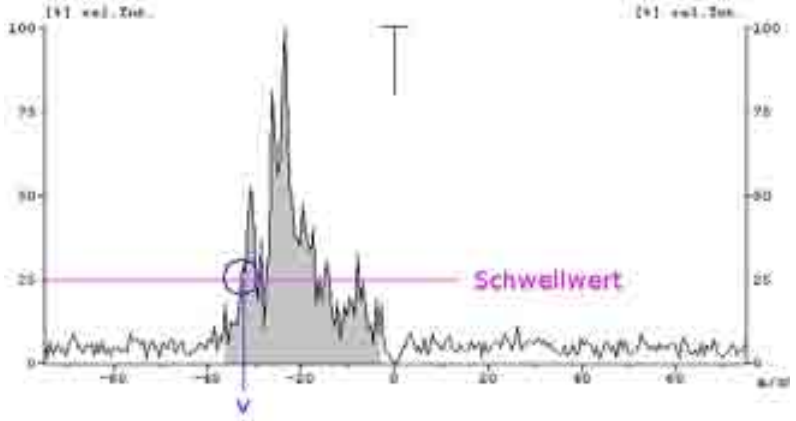

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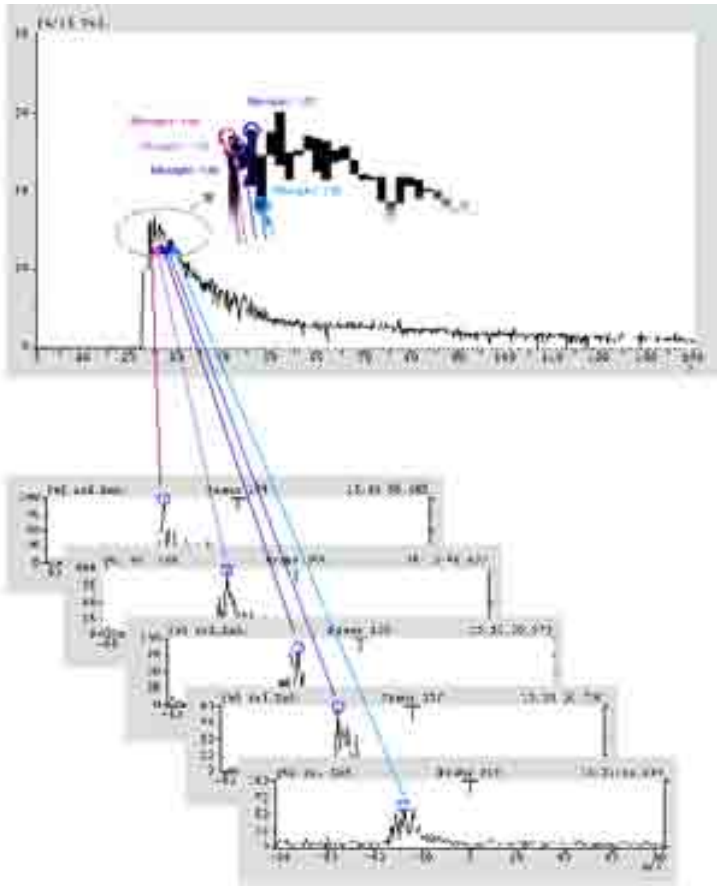

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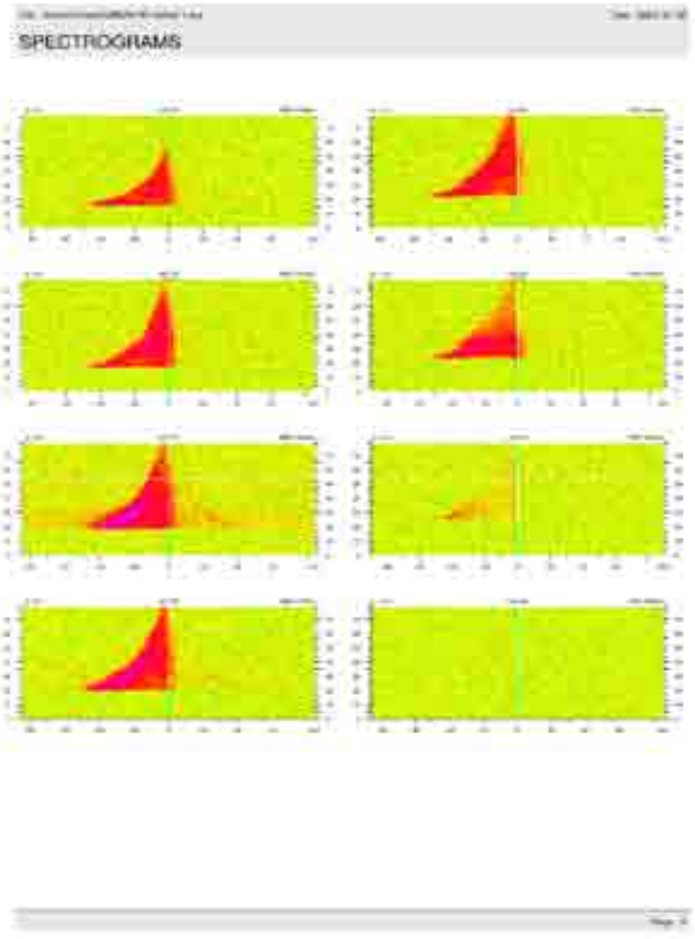
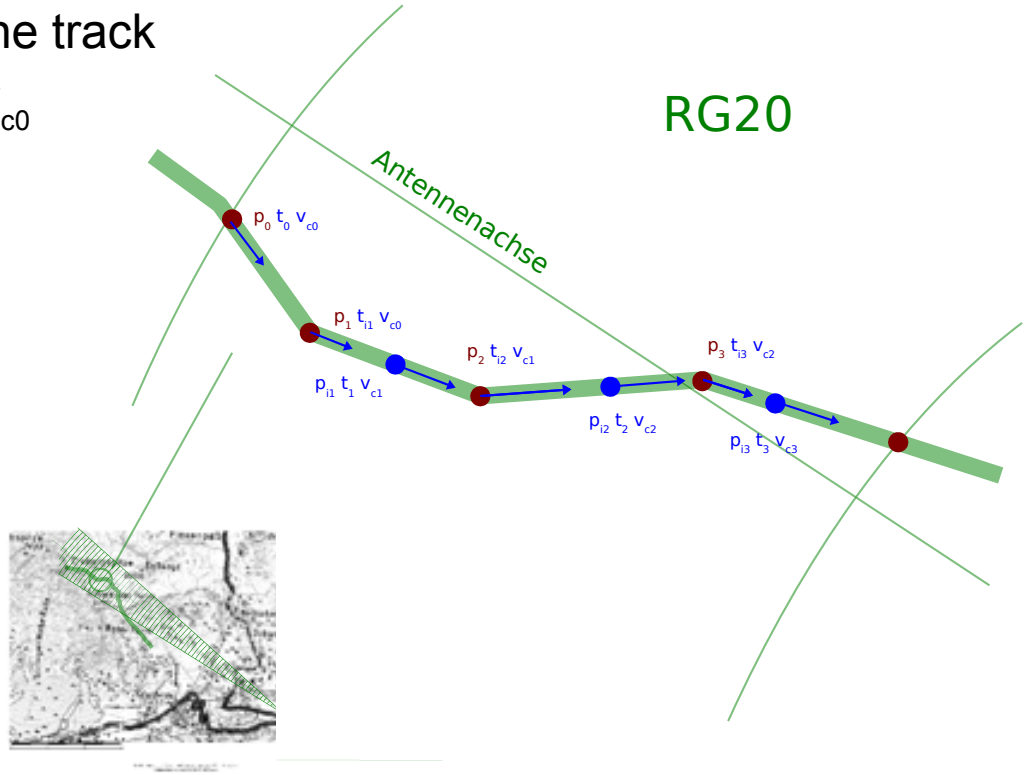


# Data Display

## Data Analysis

- Front Velocity
  - Profile of the avalanche track
  - Calculation of $t_0$ and $v_{c0}$
  - $p_1$ ➡ $t_{i1} = \frac{\overline{p_0 p_1}}{v_{c0}}$
  - $p_2$ ➡ $t_{i2} = t_{i1} + \frac{\overline{p_1 p_2}}{v_{c0}}$
  - Points between

$$p_{i1} = \vec{p}_1 + v_{c0} \cdot (t_1 - t_{i1}) \cdot \frac{\overrightarrow{p_1 p_2}}{\overline{p_1 p_2}}$$



# Data Display

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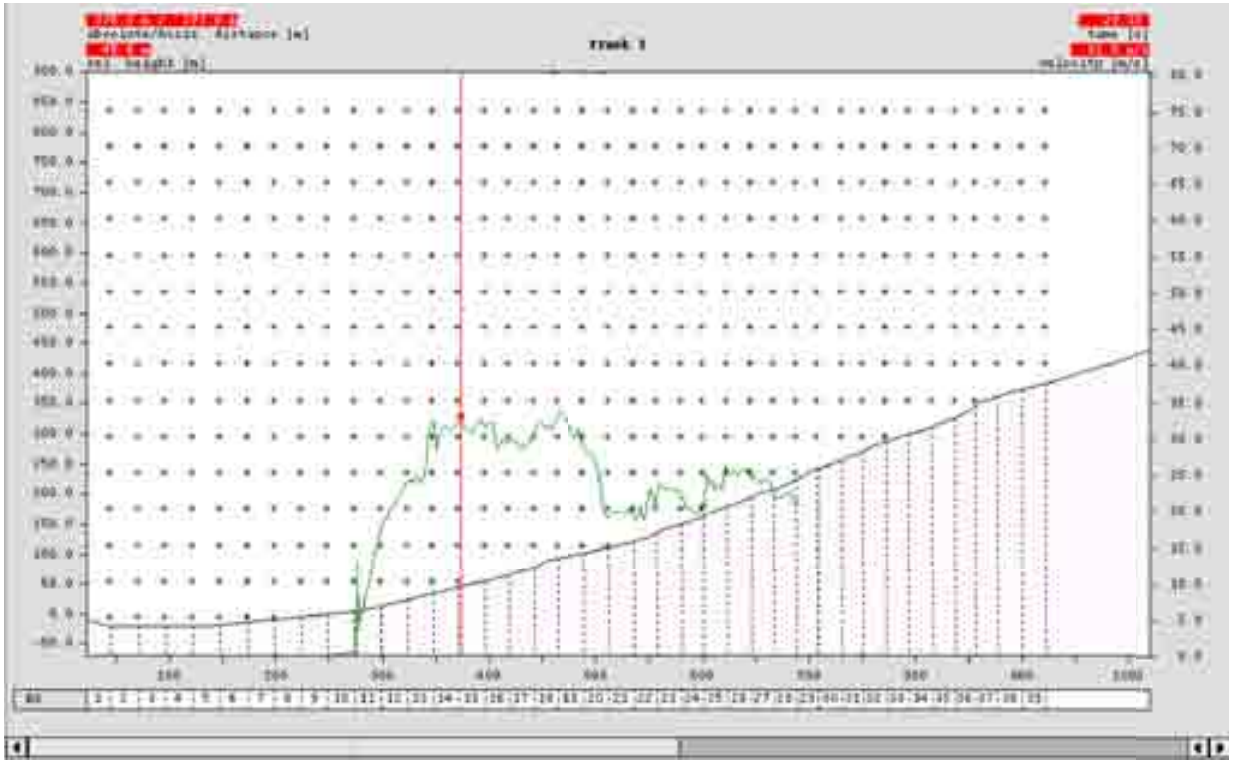

# Data Display

## Display

- Photo View
  - Max. Velocity
  - Velocity @ max. intensity
- Velocity View
  - Detailed velocity info

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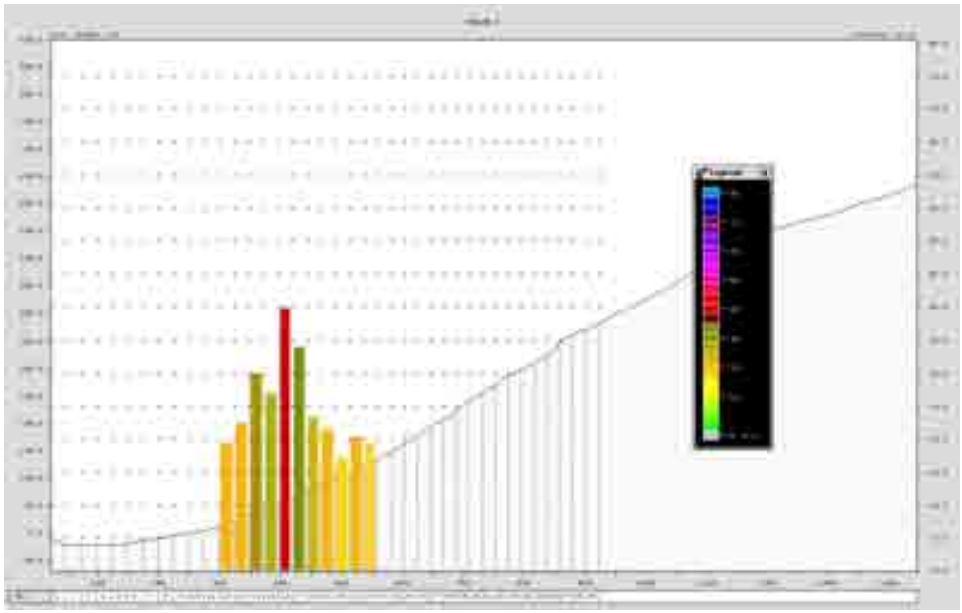


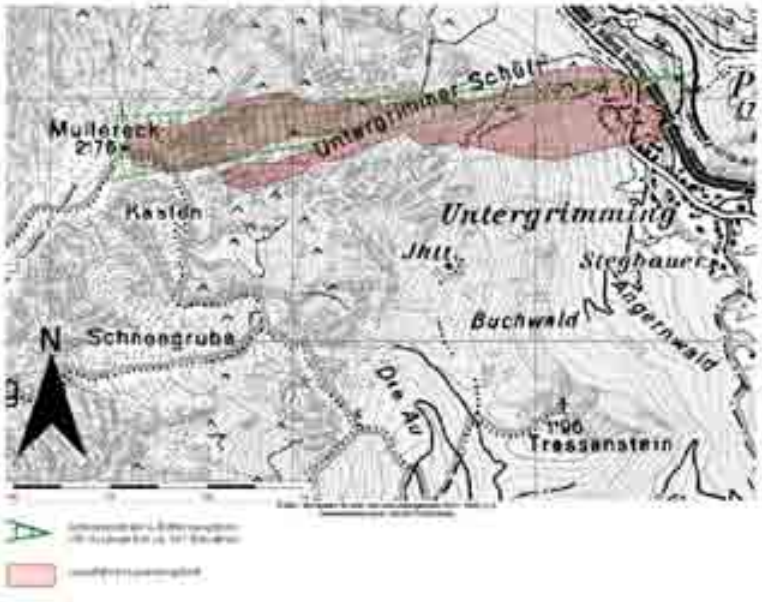
# Project Avalanche Radar „Grimming“

## LAW 9 Radar „Grimming“

- Located at the road B145 near Untergrimming and Pürgg
- 2 antennas with different beam shapes
- Observes the “Multereck” avalanche
  - natural avalanche events
- Developed between 2002 and 2004
- Since 2005 test operations
  - collecting data
  - 25 GB of data in season 2006/2007
  - ~ 100 movements at the beginning of the slope
  - Velocities between 10 m/s and 30 m/s
- Outlook: automatically switching of traffic lights to stop the traffic in case of avalanche events

# Project Avalanche Radar „Grimming“

## General Layout




# Project Avalanche Radar „Grimming“

Antenna Footprint

Primary antenna : Parabolic
- ~5° HPBW
- covers the starting area of the avalanche track non-stop
- responsible for alarm generating

Secondary antenna : Patch
- 10° x 30°
- after an alarm switching between both antennas during the measurement to cover the slope

Thank you for your attention !!