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Comparison of Q-bursts detected near the Earth's surface and 140 m below ground level

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Q-bursts are signatures of exceptionally powerful lightning strokes which produce intense radio waves typically in the extremely low frequency band (ELF, 3Hz-3kHz). Due to the finite conductivity of the Earth's surface, radio waves in this frequency range can be also detected in greater depths. While the penetration of electromagnetic (EM) waves in a conducting half space has been investigated and utilized, e.g., under water for submarine radio communication, very few field measurements consider the subsurface detection of ELF waves in the continental crust.

In this work, Q-bursts recorded in near surface and corresponding underground ELF band observations are compared in order to characterize the frequency dependent effect of the upper section of the Earth's crust on the spectrum of the Q-burst signals.

Practically co-located, but not simultaneous quasi-surface and underground temporal ELF band magnetic field measurements were made near Mátraszentimre, in the Mátra Mountains, Hungary. The underground measurement was carried out inside a mine shaft in the Matra Gravitational and Geophysical Laboratory (MGGL) at a depth of 140 m. ELF observations from two permanent recording stations in the Széchenyi István Geophysical Observatory (NCK, Hungary) and in Hylaty (HYL, Poland), less than 250 km away from MGGL, were involved in the analysis to deduce the transfer function between the unsynchronized quasi-surface and underground measurements in the Mátra.

The set of Q-bursts, which were parallelly detected at all three locations, was identified using GPS synchronized time stamps. Natural origin of the signals was confirmed by identifying the parent lightning strokes in the database of the World Wide Lightning Location Network (WWLLN) via matching the detection times and the corresponding source directions calculated at NCK station.

The good agreement of the results from independent Matra-NCK (5-30 Hz) and Matra-HYL (5-140

Hz) station-pairwise analyses confirm that the frequency dependence of the wave attenuation due to overlying rocks is exponential. The deduced integrated local conductivity, 30-40 S/m, of the upper section of the Earth's crust suggests that probably the soil has prominent role in attenuating ground penetrating EM waves in the ELF band.