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NOVEL APPROACHES IN MODELING OF SURFACE NMR SIGNALS FOR HYDROGEOPHYSICAL APPLICATIONS

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Surface nuclear magnetic resonance (NMR) takes advantage of precession phenomena that result from exciting groundwater hydrogen protons in the Earth's magnetic field by secondary magnetic fields generated by large surface loops. The method allows subsurface water content to be determined from inversions of measurements of a single surface loop in 1-D mode (magnetic resonance soundings, MRS) or from a series of coincident and/or offset transmitter and receiver loops in 2-D mode (magnetic resonance tomography, MRT). Until recently, computational approaches were restricted to simplified models that were not able to explore the full information content of the recorded signals or were inappropriate for complex topography or subsurface structures. Major oversimplifications included computations of spin dynamics that are based on incomplete description of double pulse sequences or assumptions of (a) regularly shaped surface loops on a flat earth, (b) a 1-D subsurface resistivity distribution, or (c) ideal excitation pulses in terms of duration, time-domain shape, and carrier frequency.

To improve significantly the modeling of surface NMR signals we developed an innovative computational approach that includes the following aspects:

(i) Spatial discretization of the volume of investigation by a hierarchical irregular mesh to allow for arbitrary 3-D topography, accounting for known subsurface structures, and accurate sampling as well as efficient computation of the spatially highly oscillating NMR signal in the vicinity of the surface loops.

(ii) Accurate and efficient computation of the loop magnetic field for arbitrary topography and 3-D subsurface resistivity distribution by means of hybrid boundary-integral - finite-element methods.

(iii) Computation of the spin dynamics by numerically solving the Bloch equations, thus taking account of pulse imperfections and frequency offsets. Based on the new meshing algorithm, we introduce a computational approach for the modeling of double-pulse sequences in the highly inhomogeneous loop magnetic field.