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Powerline harmonic noise in MRS data cancellation by sinusoidal subtraction

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The surface magnetic resonance method (SNMR) is a valuable technique for hydrogeological studies, since it provides information on the porosity, hydraulic conductivity and water content. However the bad signal-to-noise ratio often encountered limits its application range. In particular, in suburban areas, strong powerline harmonics severely degrade the SNMR signals. The powerline fundamental frequency is subject to small variations in time that make high order harmonics filtering difficult using a classical notch filter without distorting the MRS signal. Harmonics cancellation using sinusoidal subtraction is an alternative, but requires a high accuracy of the instantaneous fundamental frequency value to be efficient. The power grid frequency being regulated we expect that the instantaneous frequency could be monitored with a good S/N ratio using a remote frequencemeter, synchronised with the SNMR device, and later used for processing.

Based on this accurate instantaneous frequency measurement we developed a processing method based on the subtraction of a powerline harmonics model of constant amplitudes. We performed numerical experiments to quantify the efficiency of this method, and compare it with classical notch or multi-channel filtering.

Studying real noise measurements, we encountered cases where harmonics amplitudes do not remains stable over time. We therefore proposed a classical notch or multi-channel filtering.

Hydraulic conductivity and water content. However the bad signal-to-noise ratio often encountered limits its application range. In particular, in suburban areas, strong powerline harmonics severely degrade the SNMR signals.

The harmonic model sinusoidal subtraction

The signal recorded in the reception channel can be described by the model:

\[ H(t) = \sum_{m} A_m \cos(2\pi f_m t + \phi_m) \]

where \( f_m \) is the powerline instantaneous frequency.

After spikes removal, using the measured powerline frequency, phase and amplitudes of each harmonic is determined using the cross correlation with a reference sinusoid at the harmonic frequency. The complete harmonic model is later reconstructed as follows:

\[ H(t) = \sum_{m} A_m \cos(2\pi f_m t + \phi_m) \]

Inversion method to fit time-variant amplitudes

In order to find a better solution for the case of harmonic amplitudes significantly changing over a signal length we define a new harmonic model:

\[ H(t) = \sum_{m} A_m(t)\cos(2\pi f_m(t) t + \phi_m(t)) \]

Each harmonic amplitude is defined as a linear combination of \( B \)-spline functions. The \( \alpha \)-\( \beta \) parameters can be estimated solving a linear inverse problem. This problem consists in minimizing the following cost function:

\[ \sum_{n} \left( H_n(t) - \sum_{m} A_m(t)\cos(2\pi f_m(t) t + \phi_m(t)) \right)^2 \]

Harmonic model sinusoidal subtraction

The signal recorded in the reception channel can be described by the model:

\[ H(t) = \sum_{m} A_m(t)\cos(2\pi f_m(t) t + \phi_m(t)) \]

The powerline interference component of this model takes the adaptive form:

\[ H(t) = \sum_{m} A_m(t)\cos(2\pi f_m(t) t + \phi_m(t)) \]

After spikes removal, using the measured powerline frequency, phase and amplitudes of each harmonic is determined using the cross correlation with a reference sinusoid at the harmonic frequency. The complete harmonic model is later reconstructed as follows:

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Inversion method to fit time-variant amplitudes

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Signal parameters are better recovered even with a high noise level

• Signal parameters are better recovered even with a high noise level
• Time variant harmonics amplitude inversion is promising
• Performance of filtering combination strategies remains to be evaluated on a large site database

An efficient solution to cancel powerline interferences

• Measurements of the fundamental powerline frequency is the key for a good sinusoidal subtraction

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