Transfer function application on time series

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In data analysis different spectral signal contributions often cause problems during comparison of differently shaped signals. Having to set or derive the spectral corner-frequencies for filters to find similar signal contributions in two different signals is often time consuming and depends on the experience of the data-processor, leading to leakage effects in the worst case. The Earth's magnetic field strength can be approximated by logarithmic polynomials of n-th order in the spectral domain. The roots of these polynomials can be used to derive "simplified" versions of those polynomials. From those simplified versions of two different amplitude spectra one can derive a "transformation factor" called transfer-function. These transfer-functions can be used to filter one "input-signal" so that its spectral contributions will ideally fit the spectral frequency range(s) of an "output-signal" we want to compare the former with.

Signal analysis can sometimes be time-consuming if one has to deal with the comparison of very different signals. At the Conrad Observatory we discovered a good temporal correlation of parts of two signals (GP20S3 NS gradient (B), Hall-Sensor-E-field (E)). Nevertheless their amplitude range differed a lot and a superposed spectral distribution was disguising the signal of interest (see Fig. 1 - normalized view).

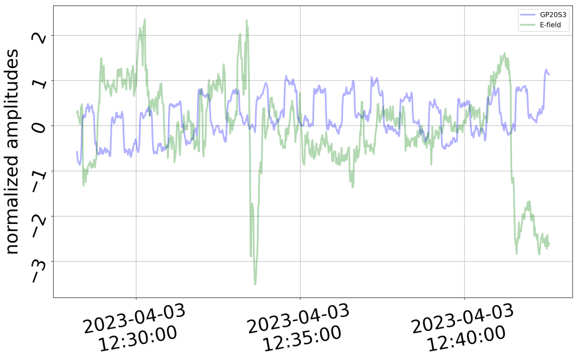

Figure 1: Unfiltered normalized time series of GP20S3 and E-field sensor.

Calculation of a linear factorization of polynomial approximations of the Fourier-spectra of both signals provided "simplified" descriptions of the zeros (GP20S3 $z_0(\omega)$) and poles (E-field $p_0(\omega)$) of a transfer function $H(\omega)$. This transfer function $H(\omega)$ was weighted by the Fourier spectra, with ω_g as the corner frequency, written below:

$$H = \frac{(1 - z_0(\omega)P)\|B(\omega)\|}{(1 - p_0(\omega)P)\|E(\omega)\|}, P = \frac{i\omega}{\omega_\mathrm{g}}.$$

The transfer function itself is weighted by a selective exponential window function to ensure that the longest and shortest periods of the signal will be the same as the desired ones. Additionally, samples closer to the poles and zeros will be weighted more strongly by the exponential window, assuring that the derived transfer function will be used closer to the poles and zeros.

By convolution of H with the E-field data in the frequency domain one is able to filter (transfer) the spectral distributions of the E-field data to a comparable amplitude and frequency range of the "desired" GP20S3 output. The filtered time series is compared with the magnetic counterpart in Fig. 2.

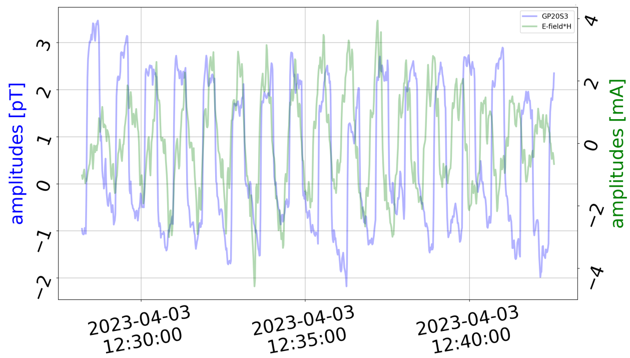

Figure 2: Filtered time series compared to magnetic (desired) timeseries.

This method enables us to compare multiple datasets with different spectral content in an efficient and fast way, "amplifying" similar spectral contributions in the input timeseries, and damping different spectral contributions, and even removing heaviside and spike-signals.

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