Disentangling Glitches

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Interferometric detector of gravitational waves (GW) are multiple - input / multiple - output (MIMO) systems. Such systems are completely described by generalized (Volterra-Wiener) transfer functions [1] :

$$y_k(t) = \sum_n y_k^{(n)}(t),$$

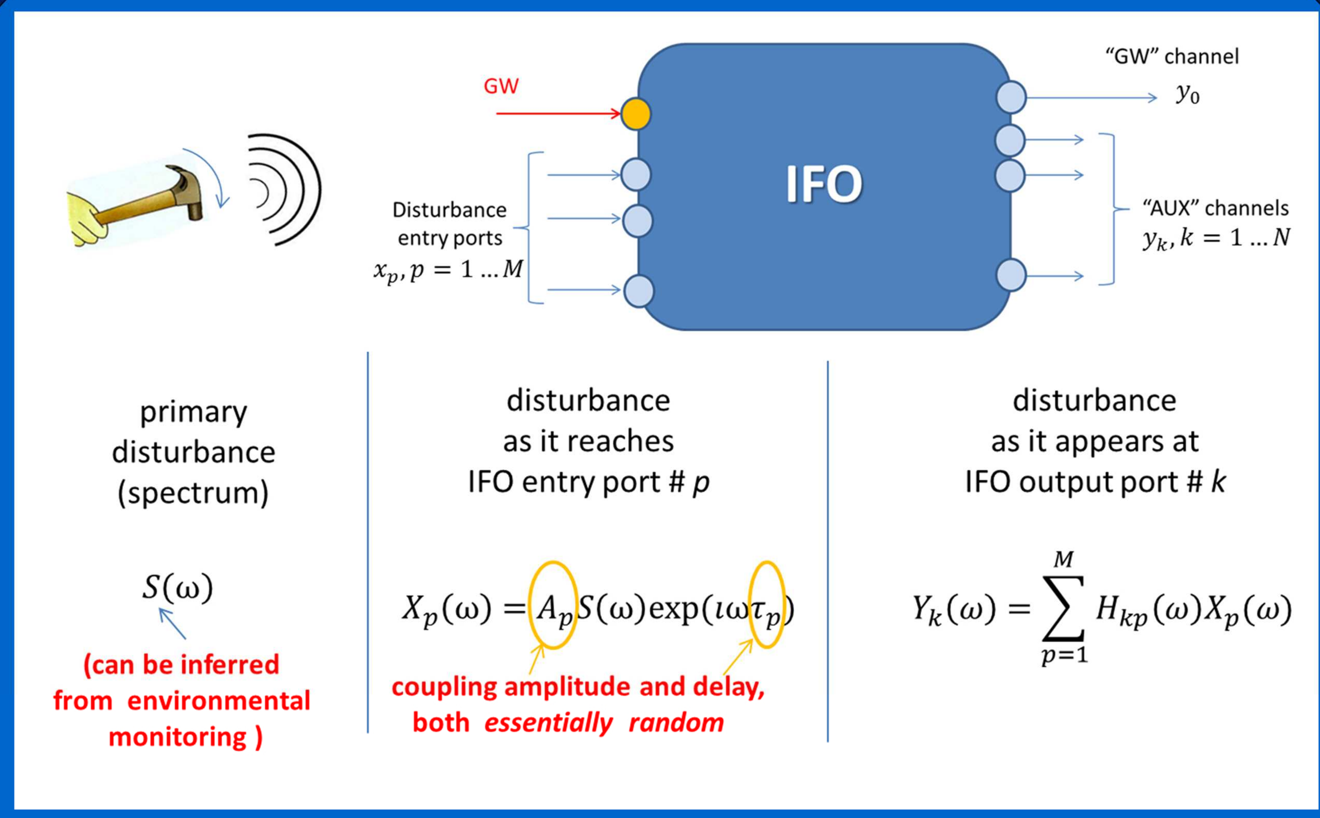
$$y_k^{(1)}(t) = \sum_{p=1}^{M} \int_{-\infty}^{\infty} H_{kp}^{(1)}(\omega) X_p(\omega) e^{-\iota\omega t} \frac{d\omega}{2\pi}$$

linear response

$$y_k^{(2)}(t) = \sum_{p,q=1}^{M} \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} H_{kpq}^{(2)}(\omega_1,\omega_2) \cdot$$

$$\cdot X_p(\omega_1) X_q(\omega_2) e^{-\iota(\omega_1+\omega_2)t} \frac{d\omega_1}{2\pi}\frac{d\omega_2}{2\pi},$$ etc (higher order nonlinear).

bilinear (quadratic) response

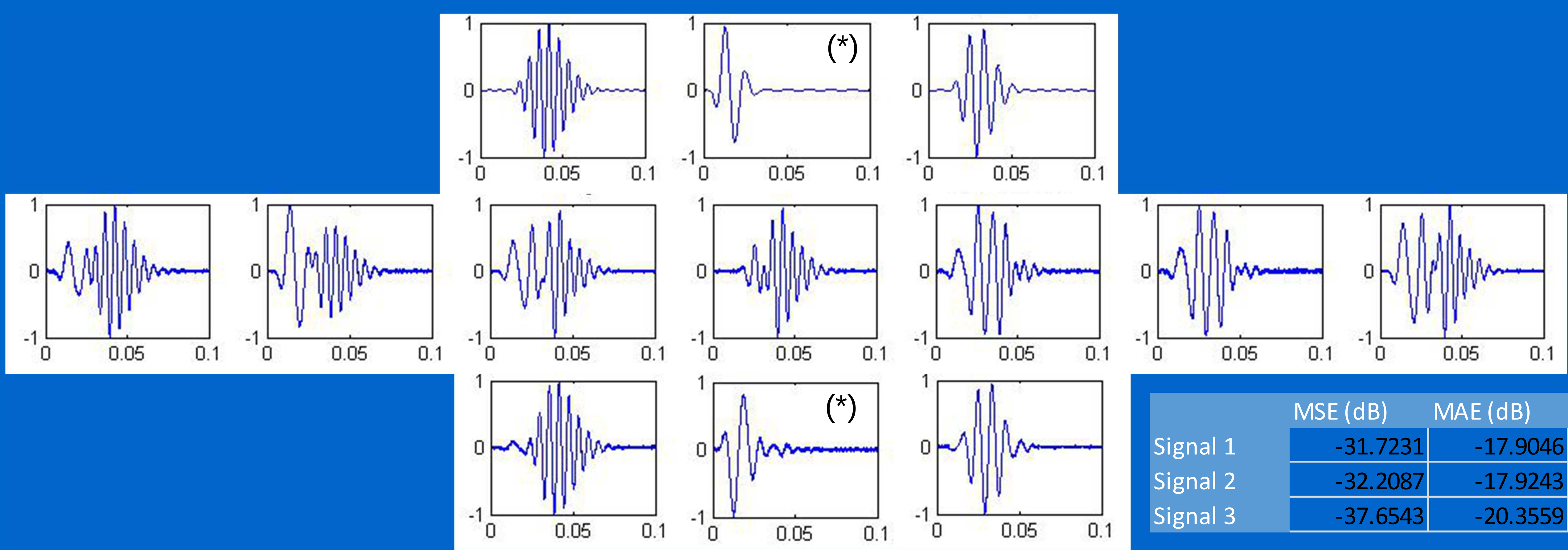


MIMO (Multiple-Input/Multiple-Output) model of interferometric GW detector. A transient disturbance reaches some "susceptible" entry ports, with random amplitudes and delays. The linear input-output relationships are described by linear transfer functions.

The (linear and nonlinear) Volterra-Wiener kernels can be *measured*, provided the relevant input/output ports are *accessible* [1]. This is *seldom* the case for disturbance entry-ports. Restrict for simplicity to *linear IFO model,* and *wideband* primary disturbances, $S(\omega) \approx S_0$, for which

$$Y_k(\omega) = S_0 \sum_{p=1}^{M} A_p H_{pk}\, e^{\iota\omega\tau_p} \longrightarrow y_k(t) = |S_0| \sum_{p=1}^{M} A_p h_{pk}[t - \tau_p - \arg(S_0)]$$

Glitches at the output of channel # *k* appear as *linear superpositions* with different (random) amplitudes and delays of the *same* (but unknown) *canonical waveforms* h_{kp} [2]. This suggests using a suitable *blind source separation* algorithm [3] to retrieve the h_{kp} from a sufficiently *redundant* set of glitchy channel-data. Preliminary numerical experiments confirm this expectation [4]. Full report in preparation.



	MSE (dB)	MAE (dB)
Signal 1	-31.7231	-17.9046
Signal 2	-32.2087	-17.9243
Signal 3	-37.6543	-20.3559

Typical performance of shifted independent component analysis. Top row: canonical waveforms whereby all transient mixtures have been obtained as a linear combinations with random amplitudes and delays in additive (-40dB) Gaussian white noise. Middle row : randomly generated mixtures. Bottom row: retrieved components (rescaled to unit maximum). Note sign ambiguity in (*). Mean square and max absolute errors in box.

References

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[2] I.M. Pinto, ''Glitchology, an Elementary Perspective,'' KAGRA document JGW-G1503692 (2015).
[3] M. Morup et al., ''Shifted Independent Component Analysis,'' Lect, Not. Compu. Sci. **4666** (2007) 89.
[4] E. Mejuto Villa, *Master Thesis* in Telecommunications Engineering, UniSannio, unpublished (2015).