

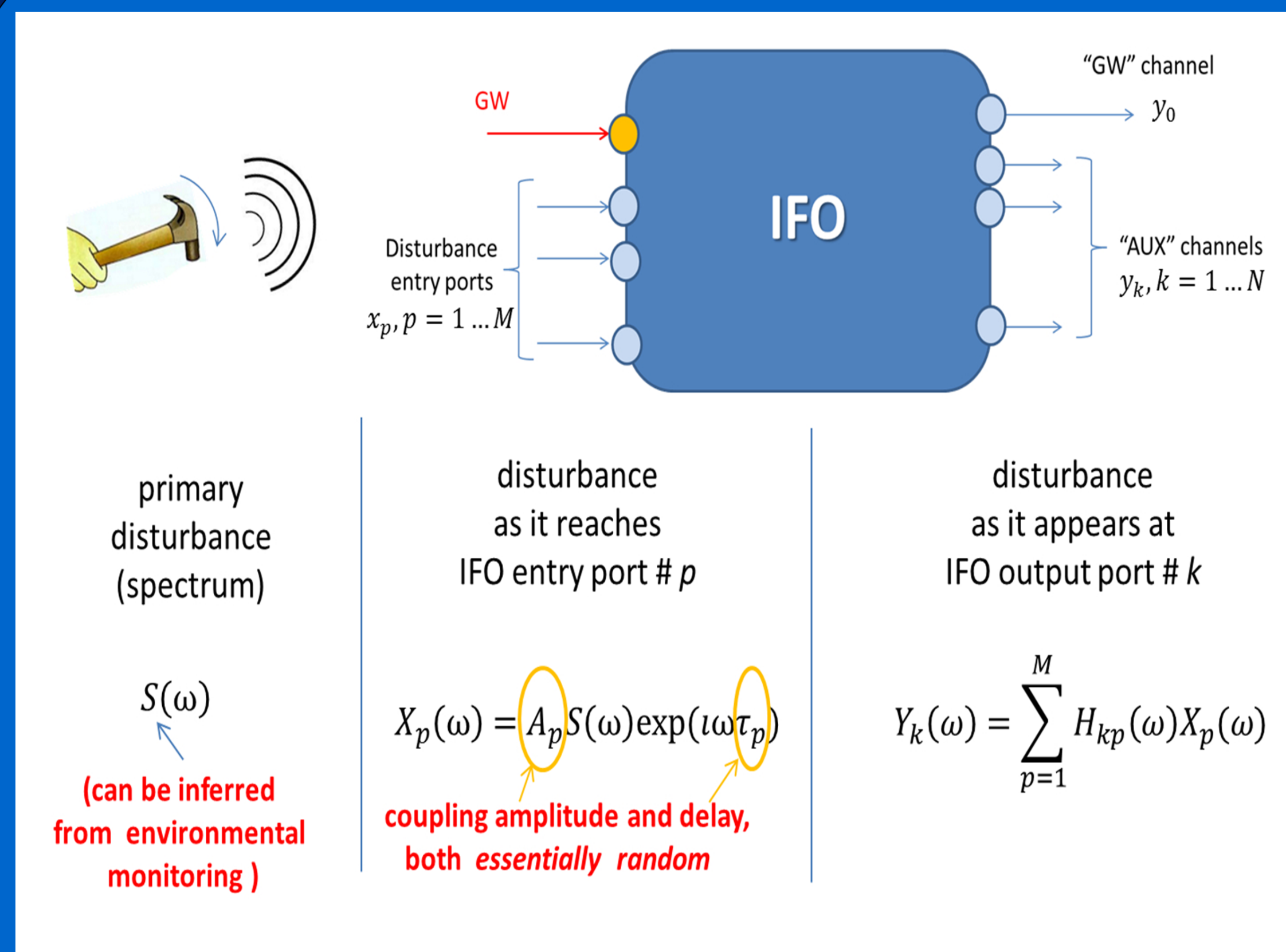
Constructing Natural Glitch Dictionaries

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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.

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

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

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

linear response

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

bilinear (quadratic) response

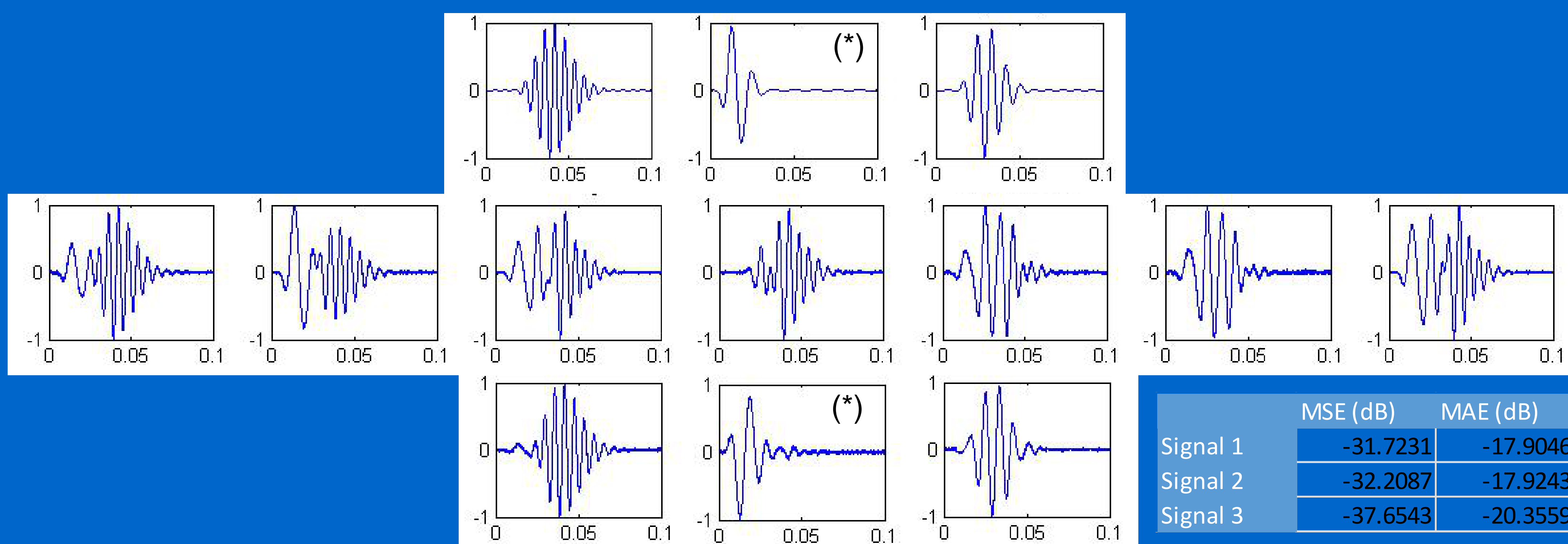
$$\cdot X_p(\omega_1) X_q(\omega_2) e^{-i(\omega_1 + \omega_2)t} \frac{d\omega_1}{2\pi} \frac{d\omega_2}{2\pi},$$

etc (higher order nonlinear).

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. We restrict for simplicity to *linear IFO model*, and *wideband* primary disturbances, $S(\omega) \approx S_0$, for which

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

Hence, *glitches* at the output of channel # k are *linear superpositions* with different (random) amplitudes and delays of the *same* (yet unknown) *canonical waveforms* $h_{k|p}$ [2]. These form a *natural dictionary* for representing (and potentially subtracting) glitches in that channel. They $h_{k|p}$ can be singled out using a *blind source separation* algorithm [3] from a sufficiently *redundant* [4] set of glitchy data. Illustrative numerical experiments are shown below.



Typical performance of BSS (SICA).

Top row: three elementary (LTI canonical) waveforms.

Middle row: linear mixtures of the above with random amplitudes and delays in additive (-40dB) Gaussian white noise.

Bottom row: retrieved components (rescaled to unit max). Note sign ambiguity in (*). Mean square and max absolute errors in box.

References

- [1] M. Schetzen, *The Volterra and Wiener Theories of Nonlinear Systems*, Krieger (2006).
- [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).