Detecting Nonlinear Modules in a Dynamic Network: A Step-by-Step Procedure

M. Schoukens and P.M.J. Van den Hof

MARIE CURIE ACTIONS

erc

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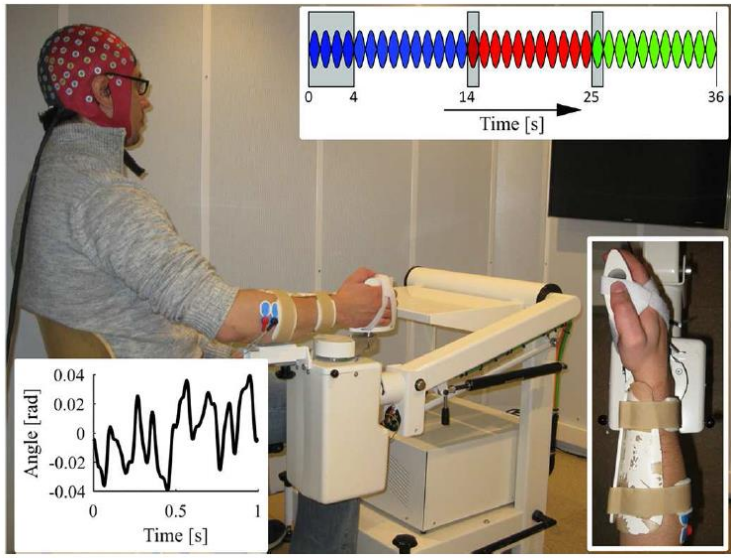
EE / Control Systems

What?



marsdd.com

Overview

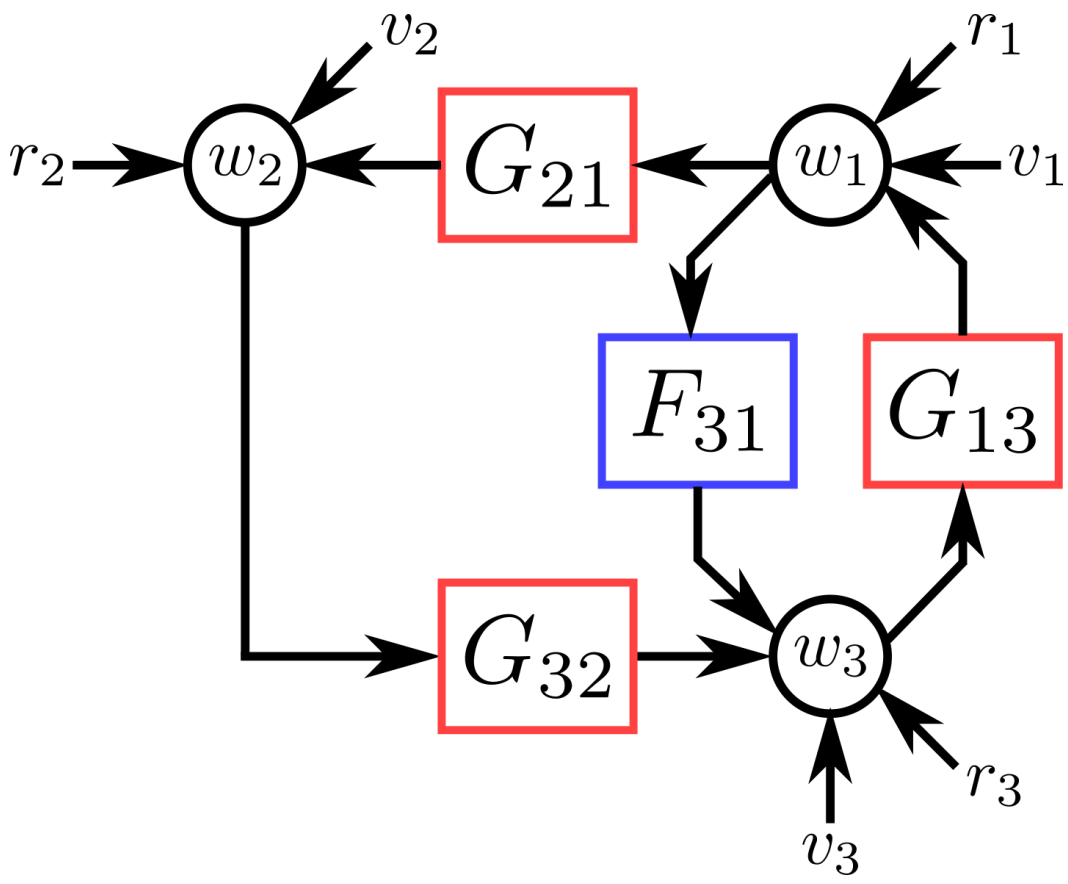
- Dynamic Networks

  Best Linear Approximation

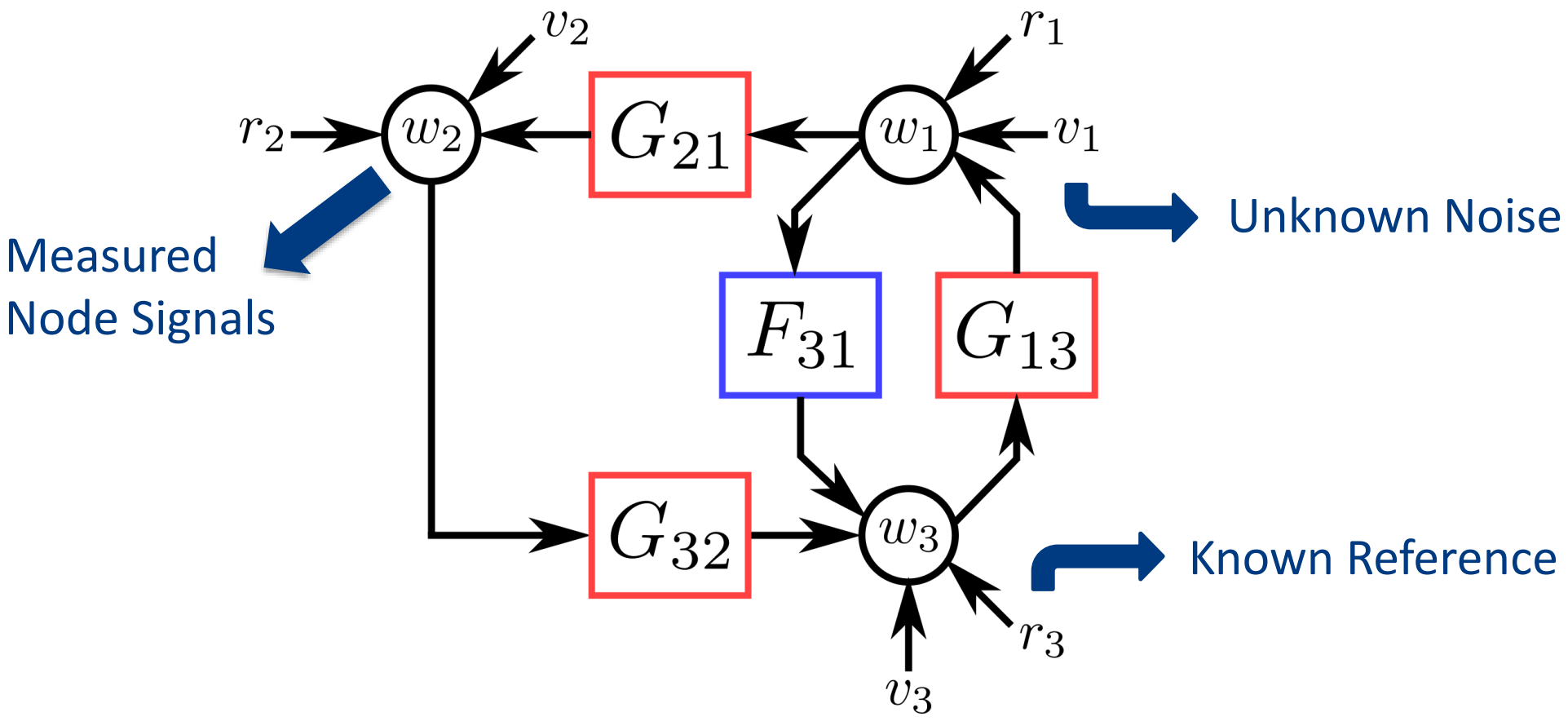
  Nonlinearity Detection in Dynamic Networks

  Conclusions

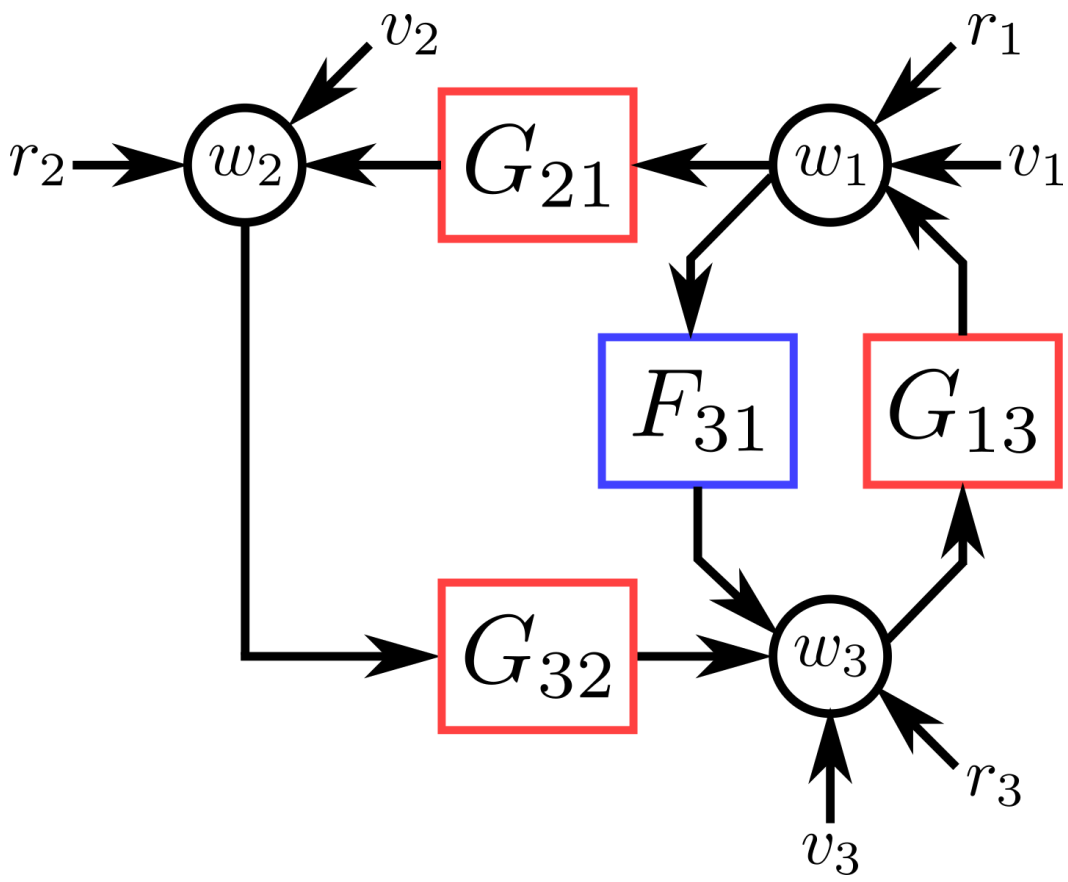
Dynamic Networks



Dynamic Networks



Dynamic Networks



Can we localize and quantify the nonlinear behavior in the network?

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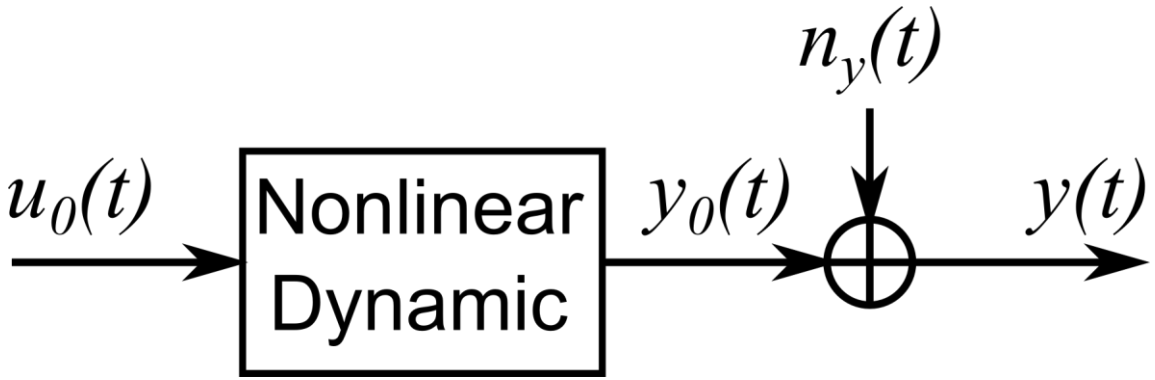
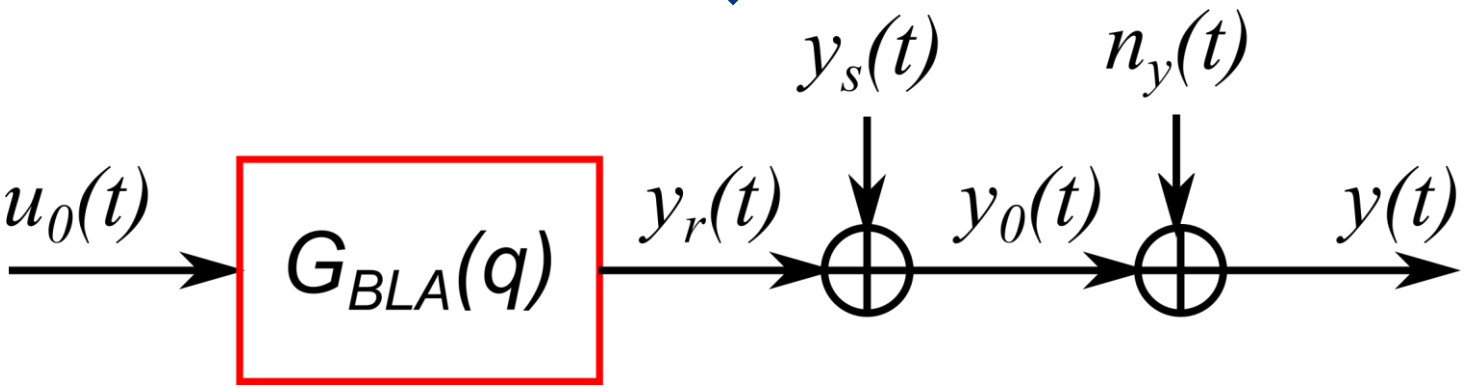
Best Linear Approximation: Definition



Minimize:

$$E_u\{|y(t) - G(q,\theta)u(t)|^2\}$$

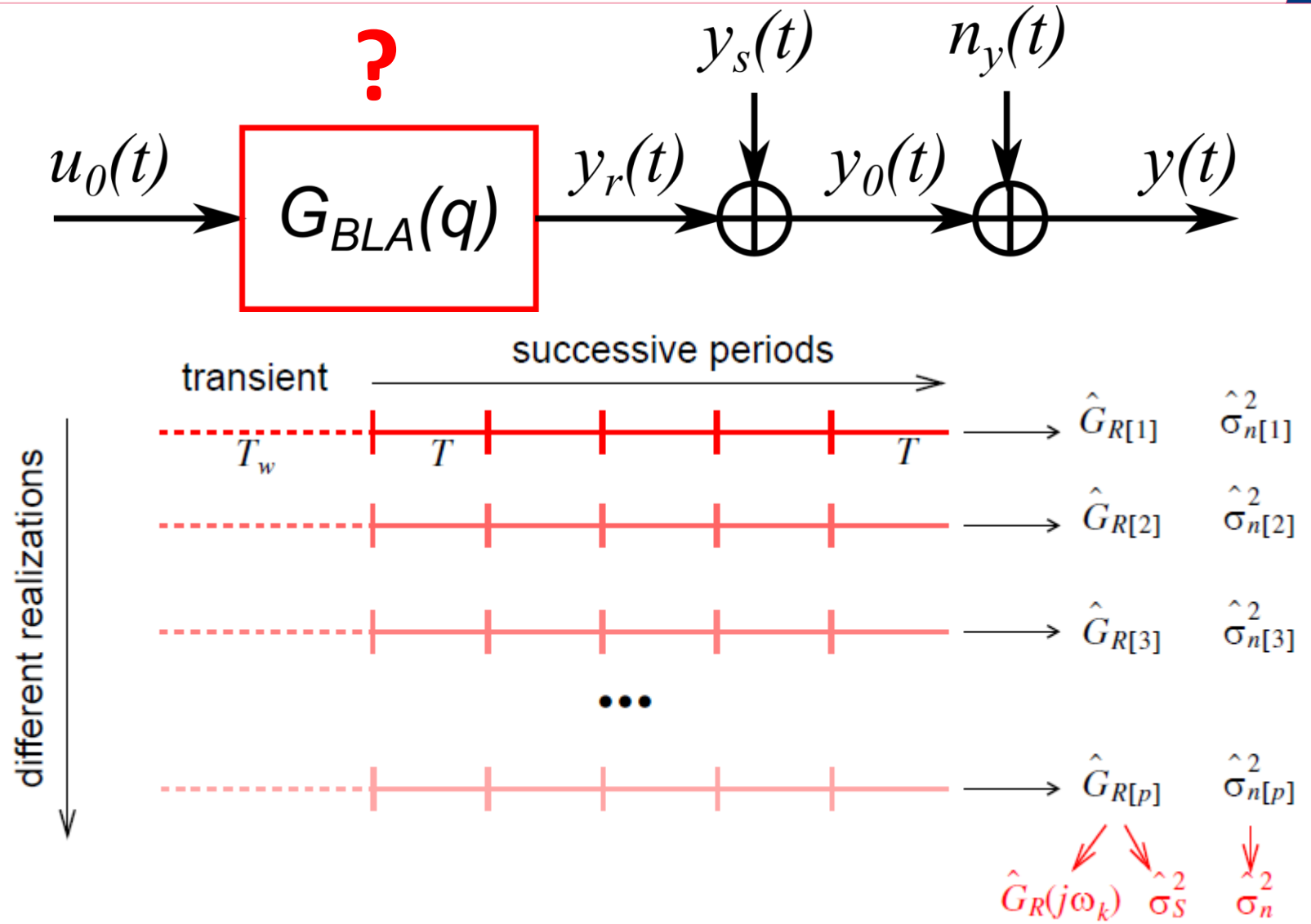


Best Linear Approximation: Experiment

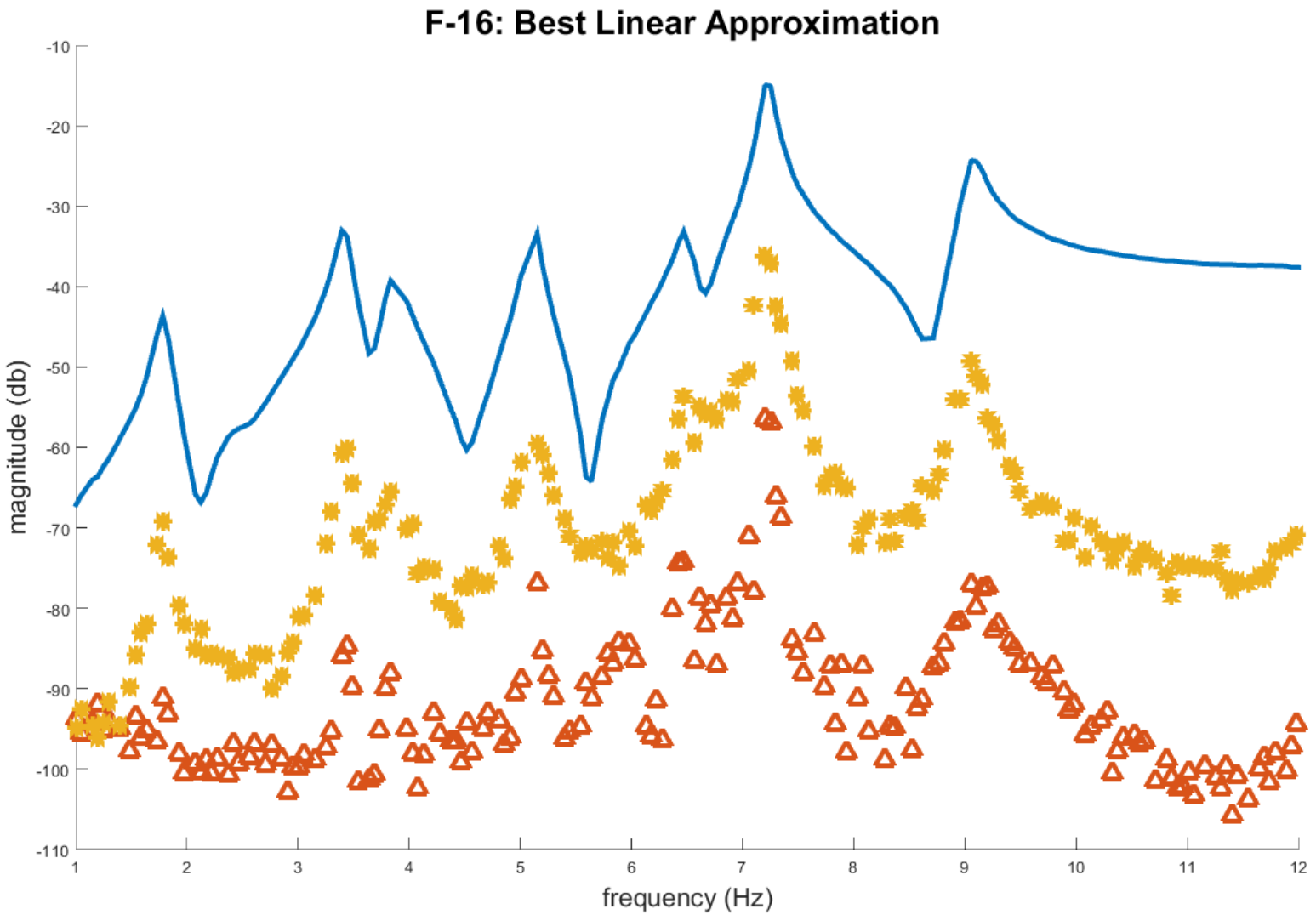
Random Phase Multisine

P Periods

M Realizations



Best Linear Approximation: Results



-- FRF

* total distortion

^ noise distortion

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Nonlinearity Detection in Dynamic Networks

Step 0: Experiment

Step 1: BLA from References to Nodes

Step 2: BLA in between Nodes

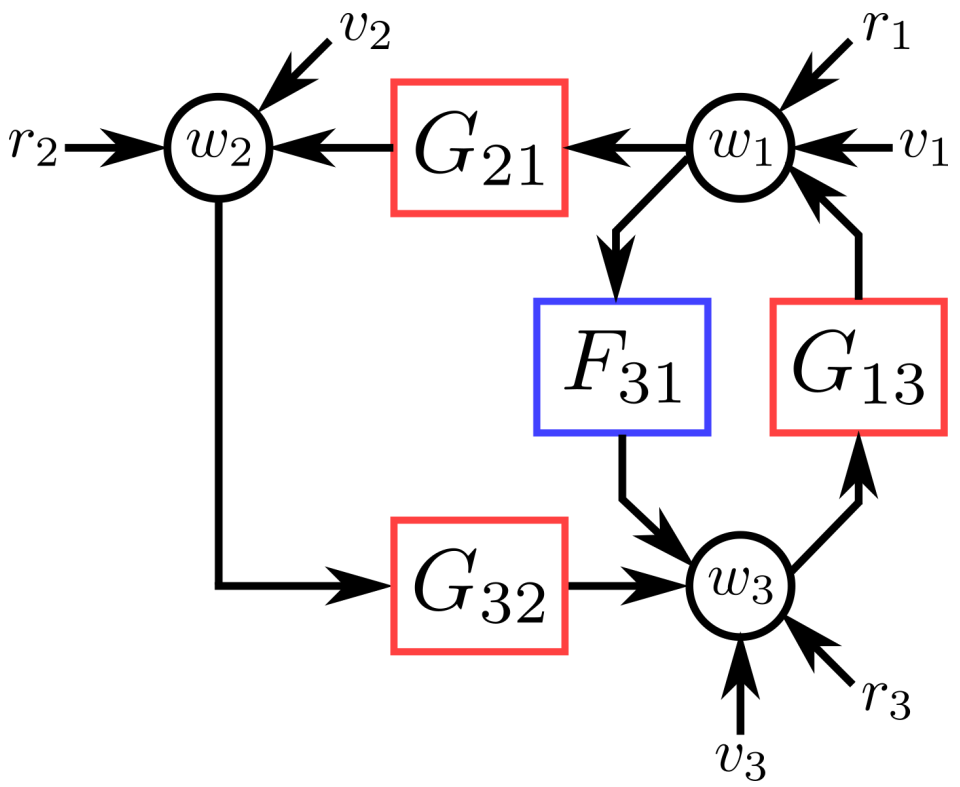
Step 3: Residual Analysis

Step 0: Experiment

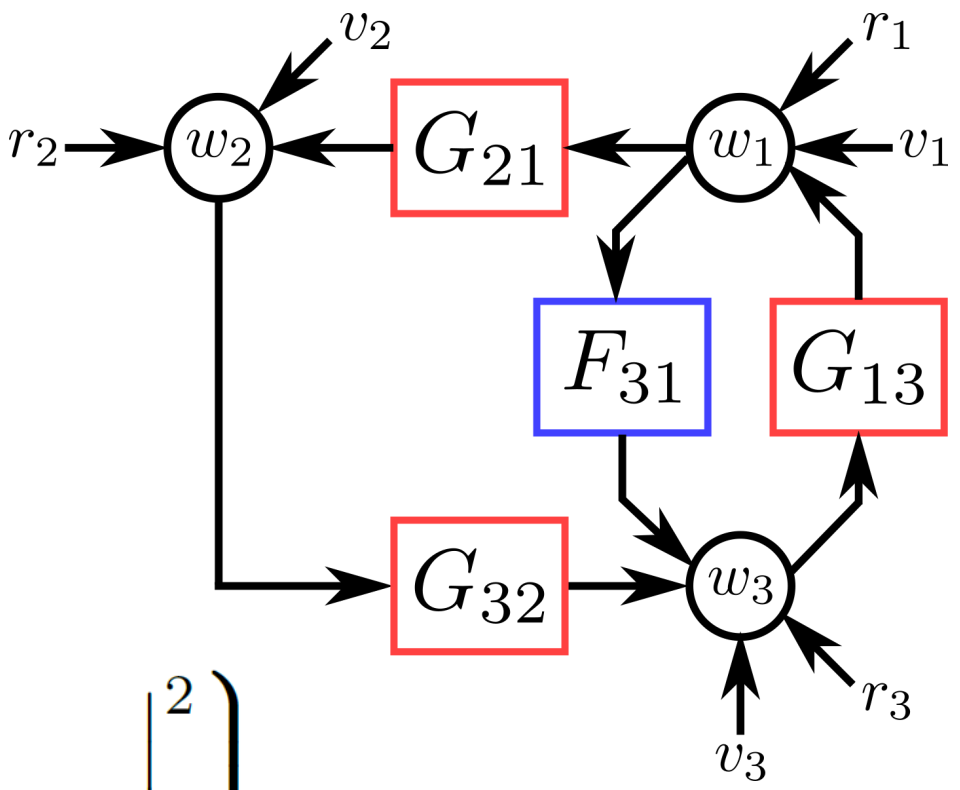
(Orthogonal) Random Phase Multisines

P Periods
M Realizations

All references excited simultaneously



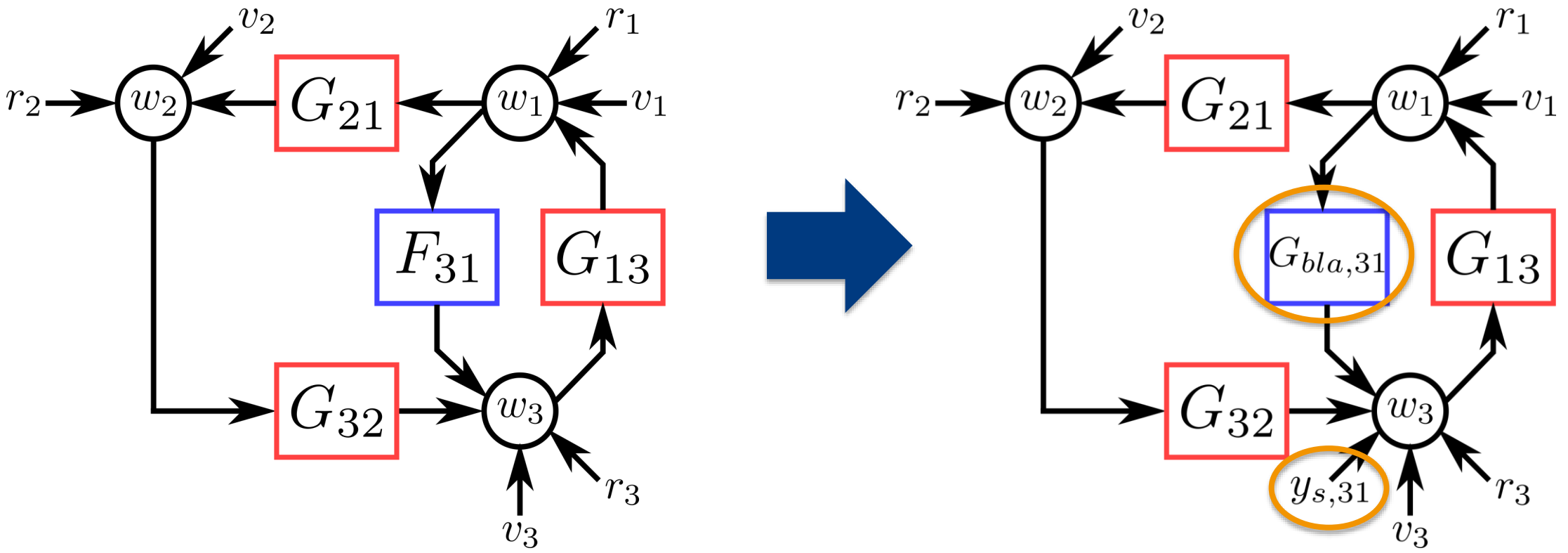
Step 1: BLA from References to Nodes



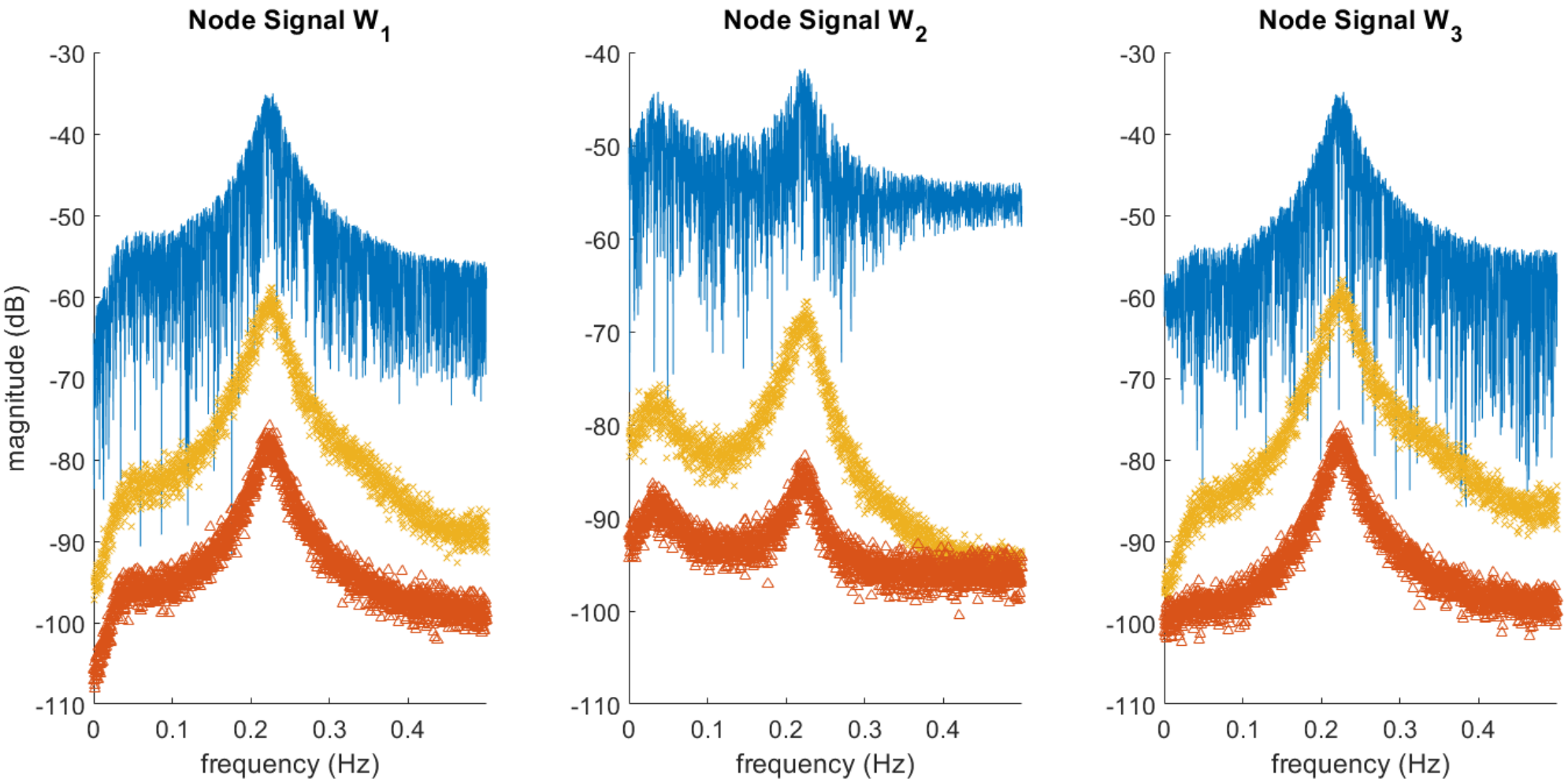
Standard MIMO BLA:

$$\mathbf{S_{bla}}(q) = \underset{\mathbf{S}(q)}{\arg\min}\, E_{r,v} \left\{ \sum_{i=1}^{L} \left| \tilde{w}_i(t) - \sum_{j=1}^{L} S_{i,r_j}(q)\tilde{r}_j(t) \right|^2 \right\}$$

Step 1: BLA from References to Nodes



Step 1: BLA from References to Nodes

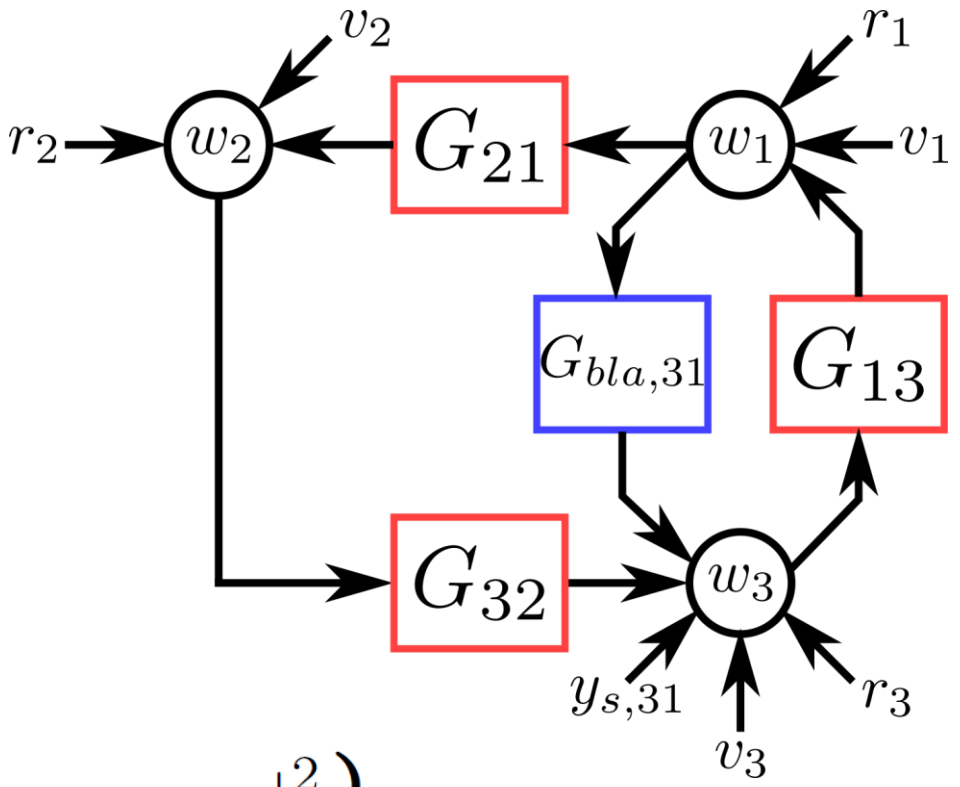


Nonlinearity Everywhere!

Step 2: BLA in between Nodes

Simulate Noiseless Node Signals:

$$\tilde{\bar{w}}_i(t) = \sum_{j=1}^{L} S_{bla,i,r_j}(q)\tilde{r}_j(t)$$

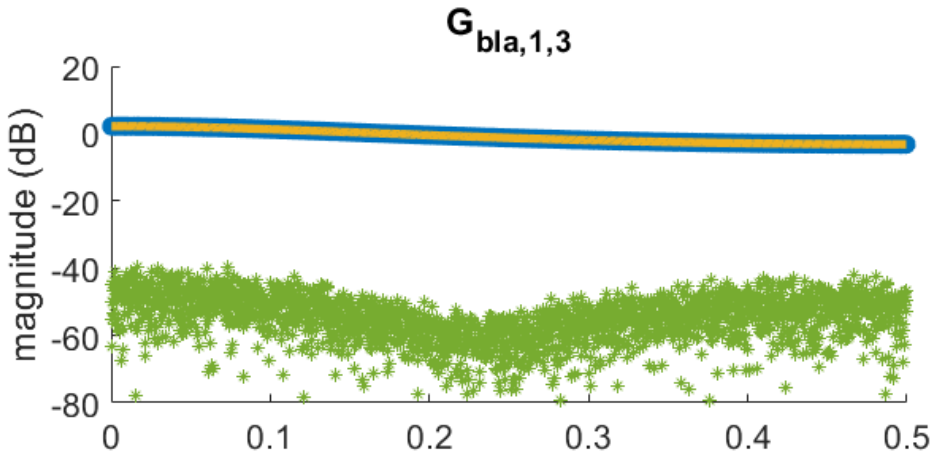


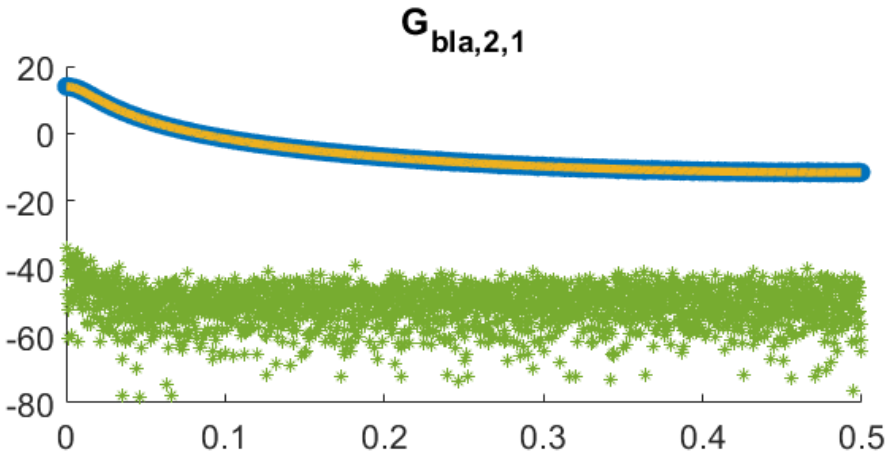
MIMO BLA in Between Nodes:

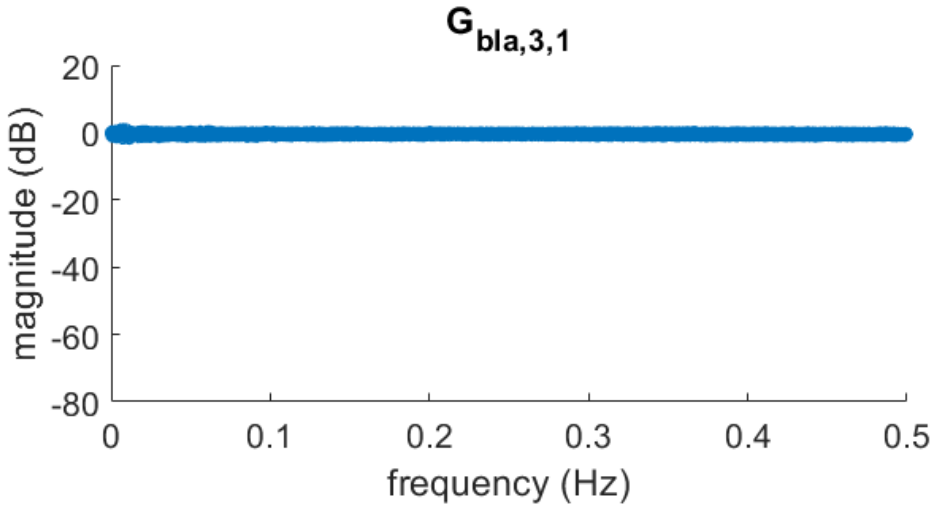
$$\mathbf{G_{bla}}(q) =$$

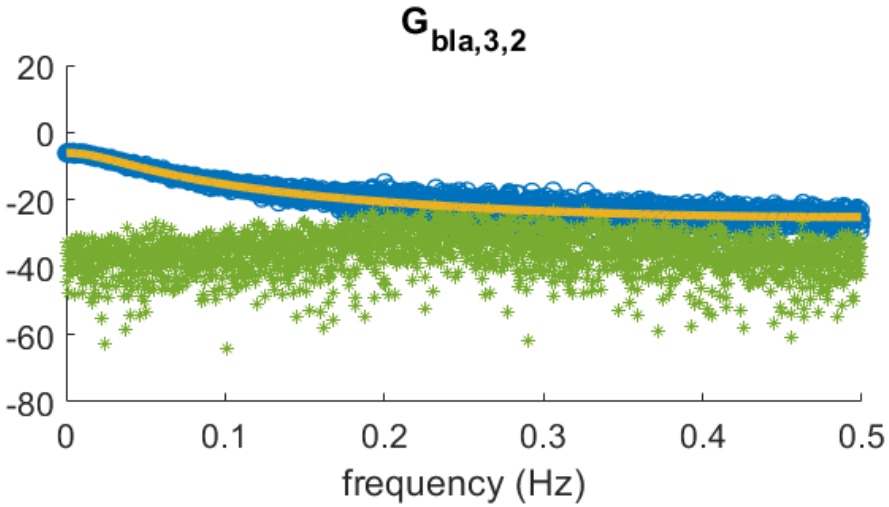
$$\arg\min_{\mathbf{G}(q)} E_{r,v}\left\{\sum_{i=1}^{L}\left|\tilde{\bar{w}}_i(t) - \tilde{r}_i(t) - \sum_{j=1,\, j\neq i}^{L} G_{i,j}(q)\tilde{\bar{w}}_j(t)\right|^2\right\}$$

Step 2: BLA in between Nodes









o FRF

-- true system

* residuals

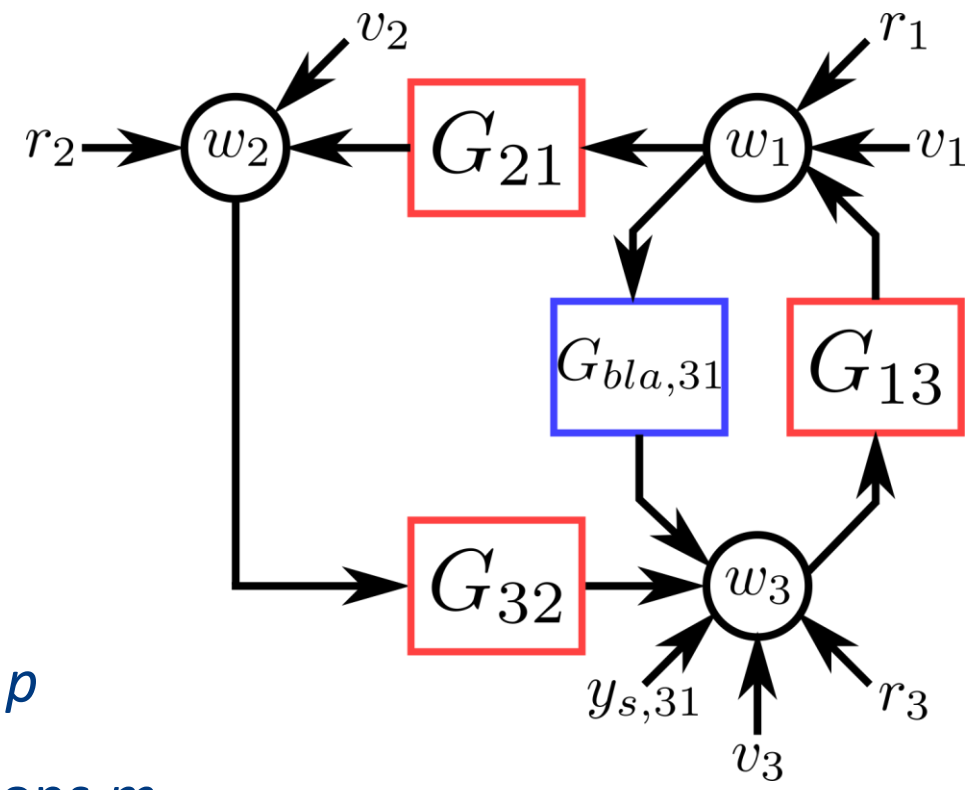
Step 3: Residual Analysis

Network Simulation:

$$\tilde{\bar{\bar{w}}}_i(t) = \tilde{r}_i(t) + \sum_{j=1,\, j\neq i}^{L} G_{bla,i,j}(q)\tilde{w}_j(t)$$

Residual Analysis:

$$e_i^{[m,p]}(j\omega) = \tilde{\bar{\bar{w}}}_i^{[m,p]}(j\omega) - \tilde{w}_i^{[m,p]}(j\omega)$$



Noise Variance:

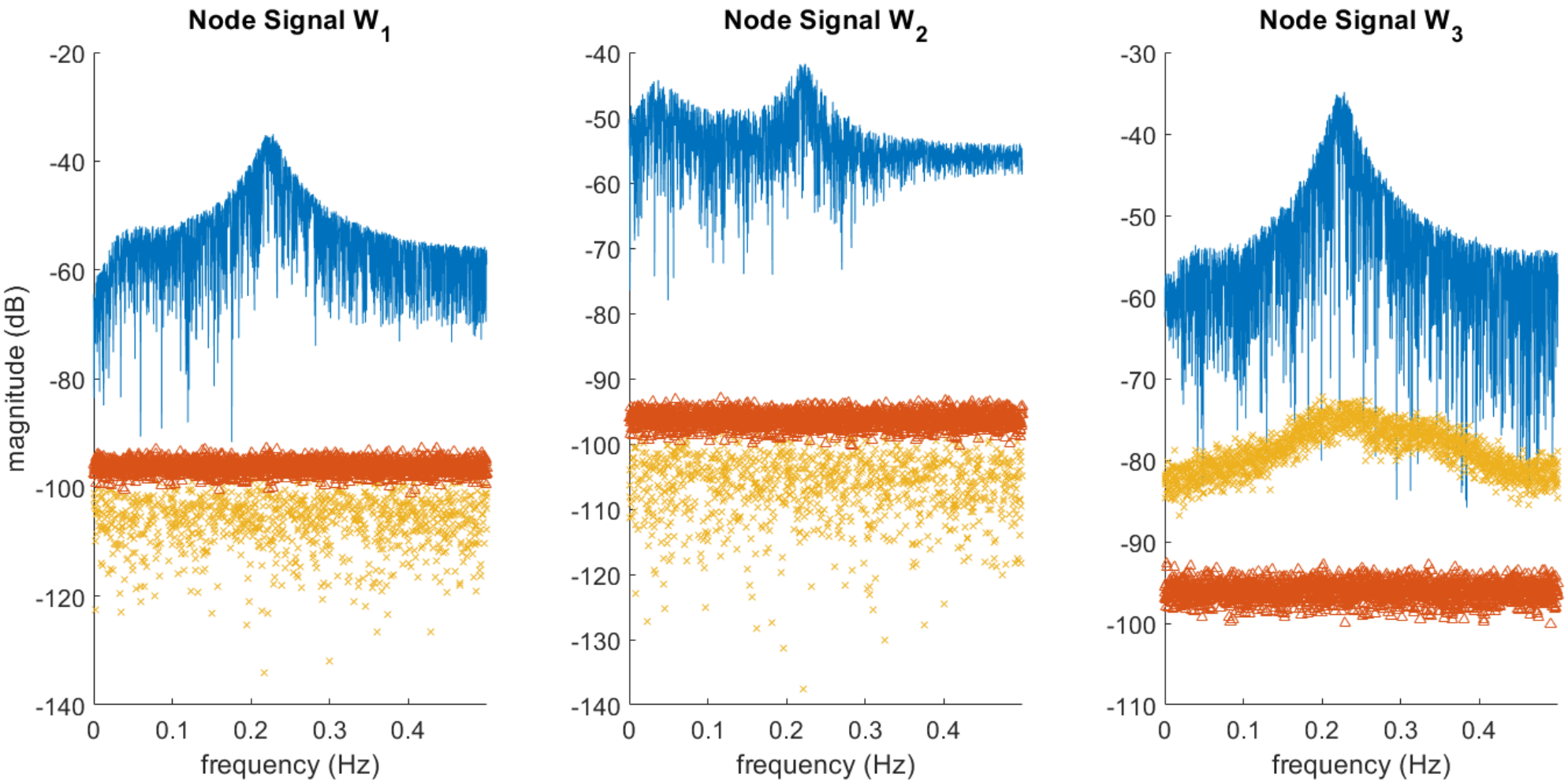
- Aperiodic Distortion: Variance over the periods *p*

Total Variance: Variance over the realizations *m*

NL Distortion Variance: Total Variance – Noise Variance

- Periodic Nonlinear Distortion

Step 3: Residual Analysis



-- node signals

* NL distortion

^ noise distortion

Only Nonlinearity Detected on Node 3!

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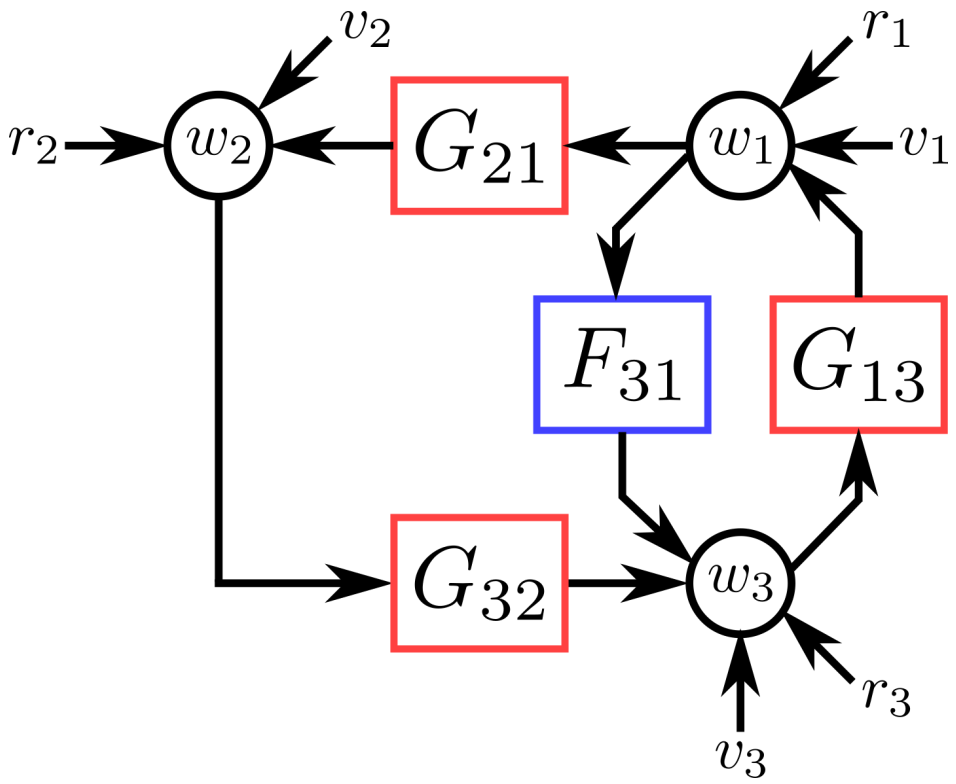
Nonlinearity Detection in Dynamic Networks

MIMO ←→ Dynamic Network point of view

Ongoing Work:

- Combining Single Experiments
- Module Level Detection



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