

VERONA, 15-19 JUNE

 **ECNDT** ^{14th}
2026
EUROPEAN CONFERENCE ON NON-DESTRUCTIVE TESTING

NUMERICAL MODELING

Modeling and Removal of Electronic Crosstalk Effects
in Ultrasound Signals via Deconvolution

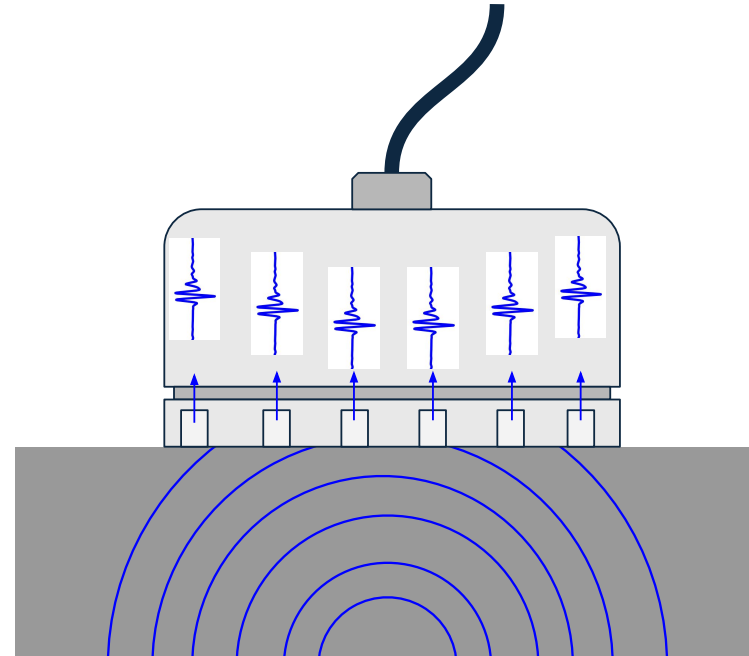
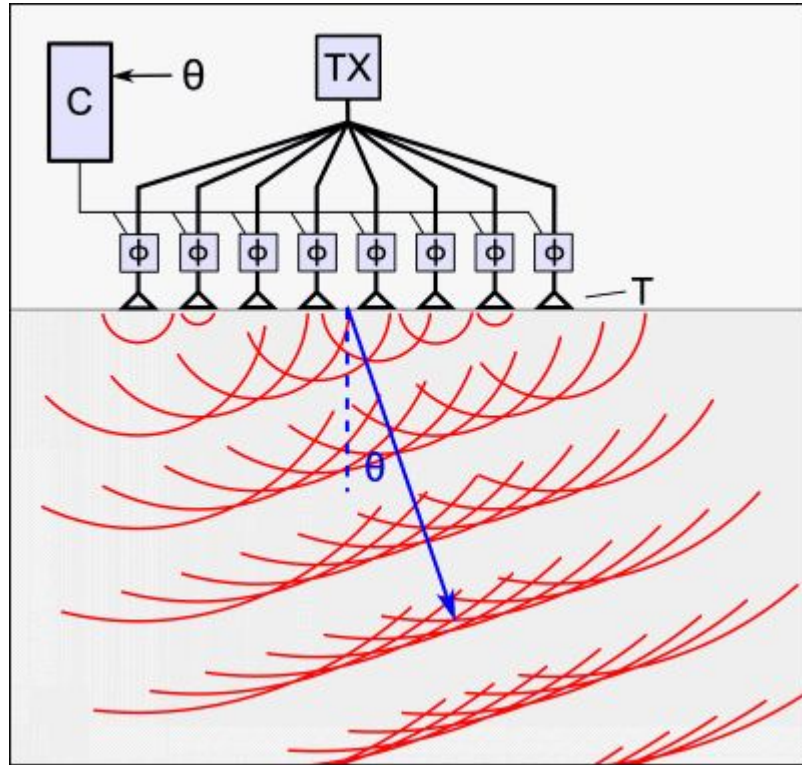
Thiago E. Kalid

Universidade Tecnológica Federal do Paraná, Curitiba, Brazil

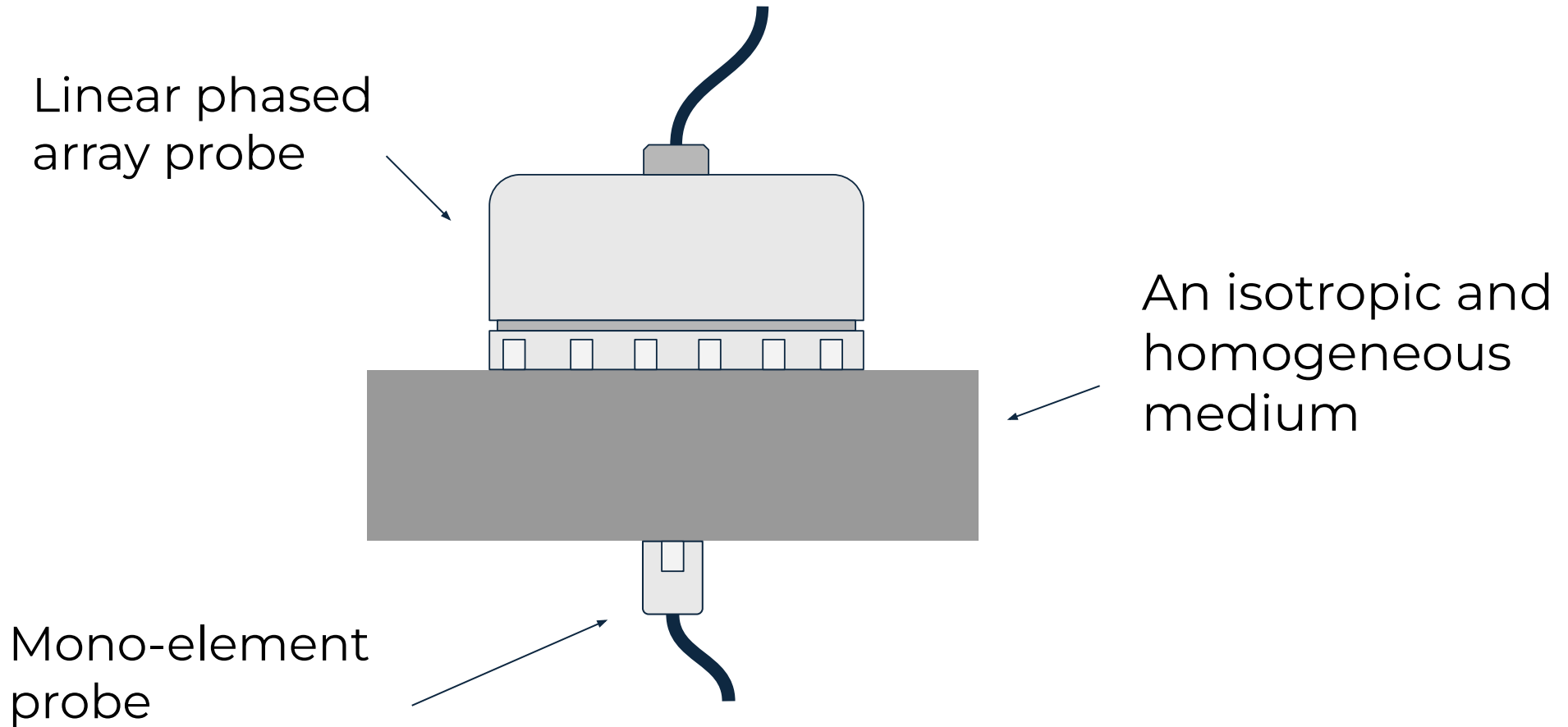
Phased array transducers are the cornerstone of modern ultrasonic inspections.



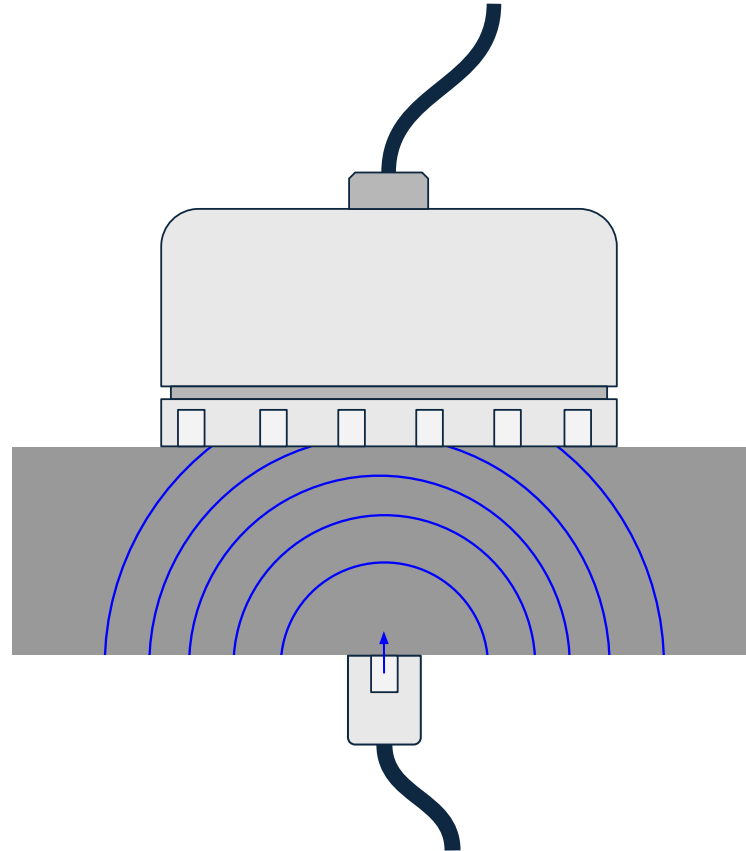
Unlike single-element probes, they increase spatial diversity of the acquisition system and allow beam steering



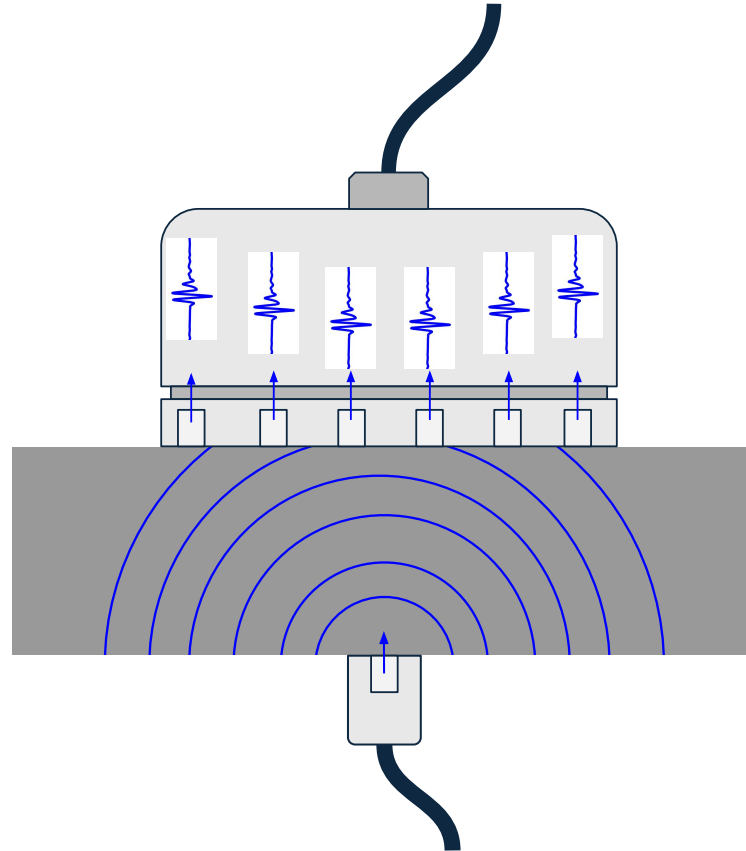
Suppose you have the following experimental setup



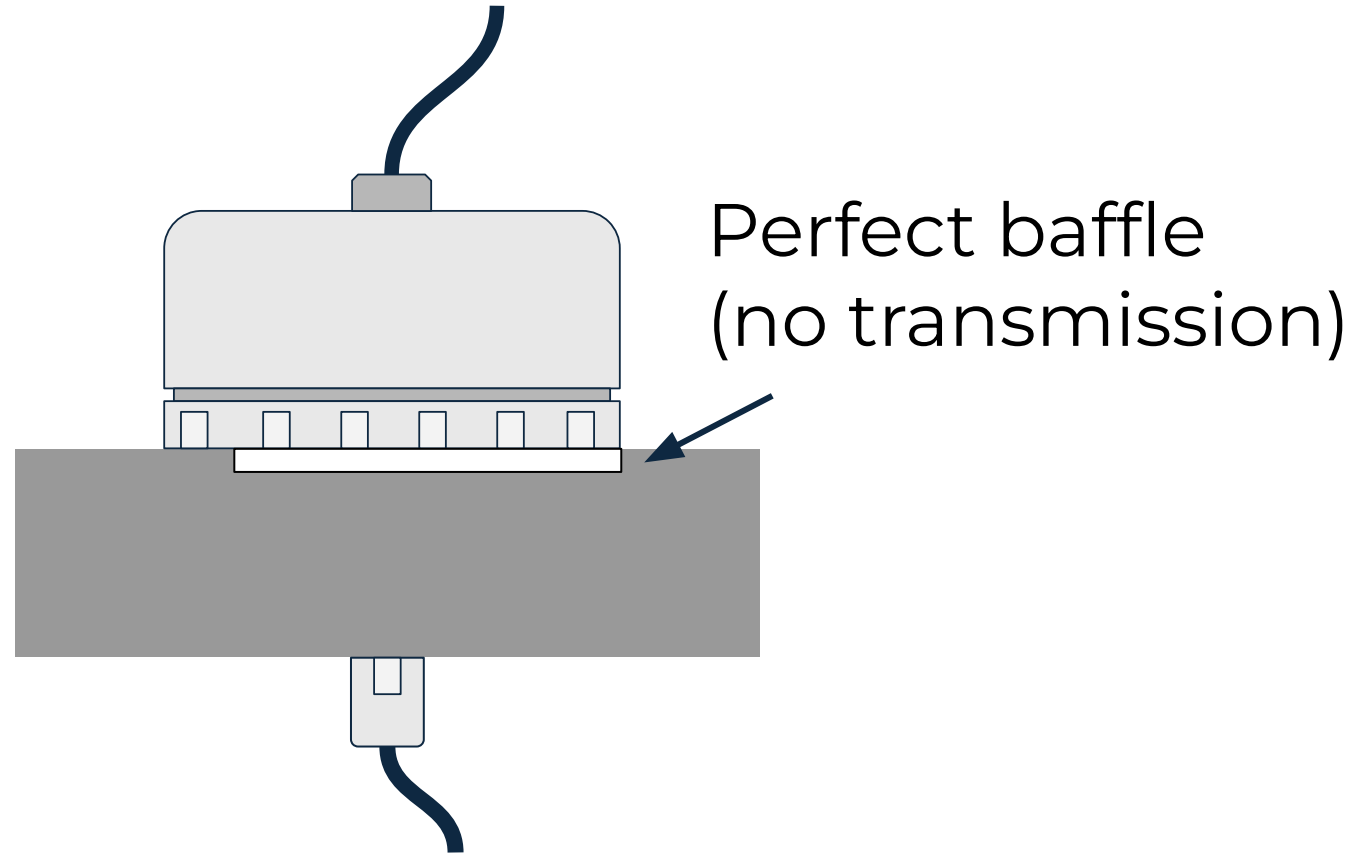
The mono-element transducer will act as a spherical wave source



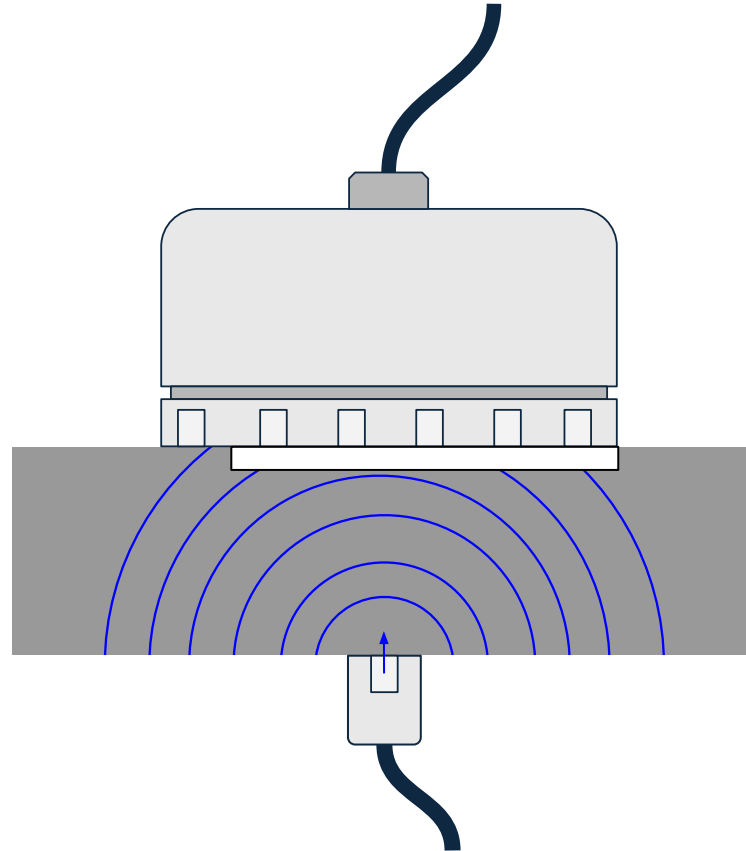
And then, the linear phased array will act as a receiver, converting field values into time-domain signals



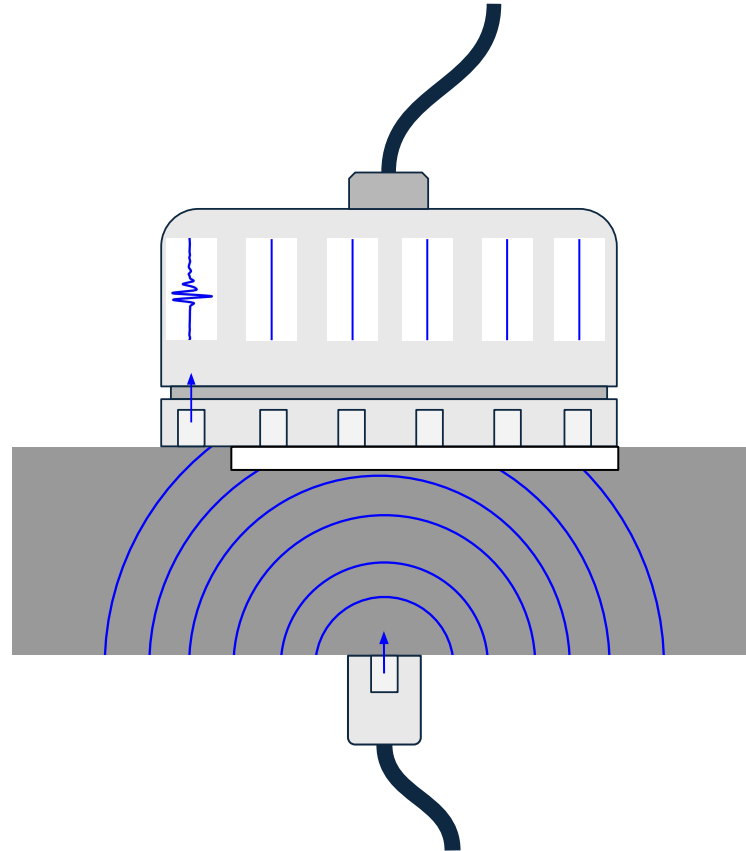
Suppose there is a perfect baffle in front of every element of the phased array, **except one**.



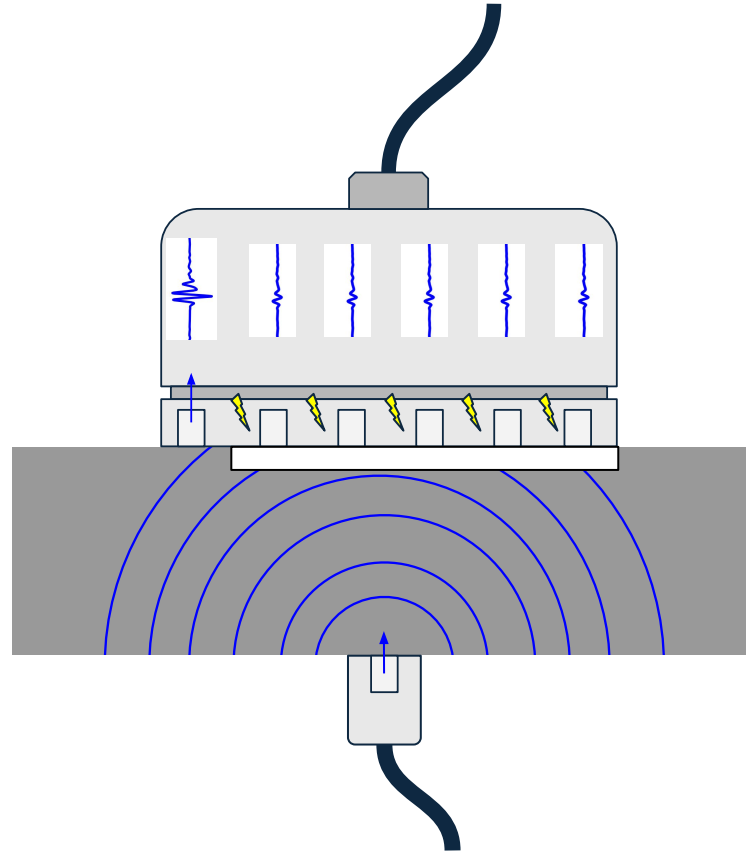
Suppose there is a perfect baffle in front of every element of the phased array, **except one.**



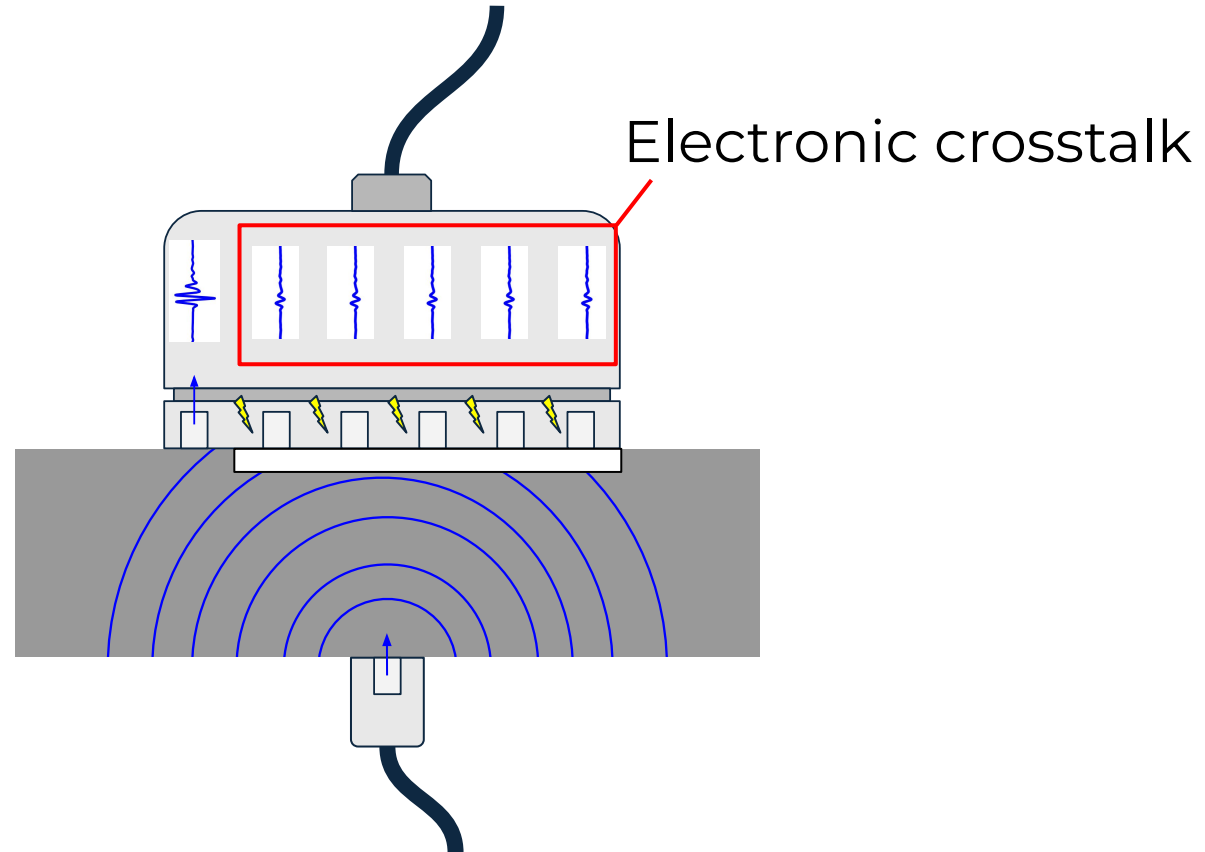
Ideally only one the unblocked element will perceive the wave field, hence will be receive the RF signal.



In practice the other channels are affected through an undesired electromagnetic coupling.



This electromagnetic induced noise is what we call **electronic crosstalk**



This effect is even more noticeable when we employ additional electronic components between the probe and acquisition system.



Proposed solution

We are proposing a method that comprises of two main stages.

Model the
crosstalk behavior
of a given probe.

Remove the crosstalk
from real acquisitions.

Imagine that it exist an ideal crosstalk-free signal F and the measured signal with crosstalk G

$$F \mapsto G$$

$$\mathcal{H}(F) = G$$

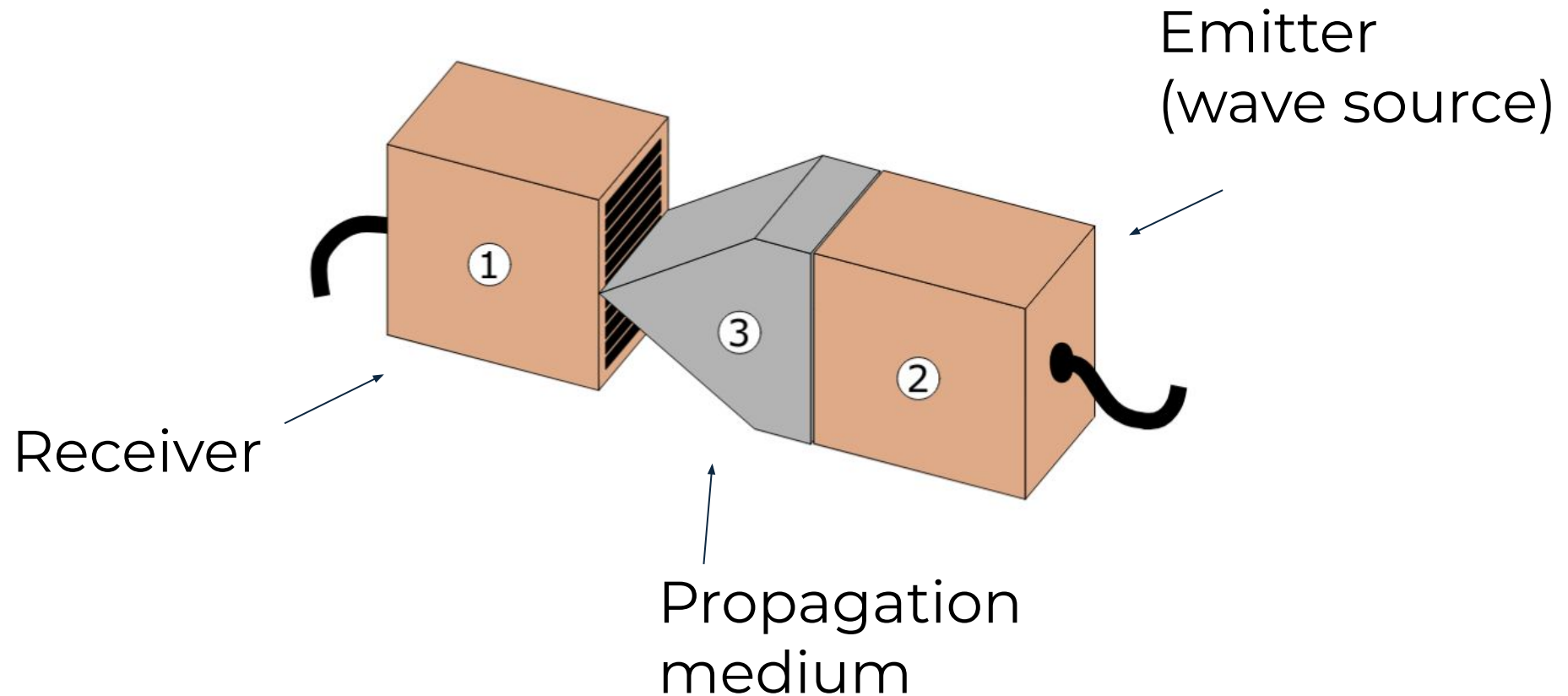
Modeling: finding H ,
given that we know F
and G

Removal: finding F ,
given that we know
 H and G

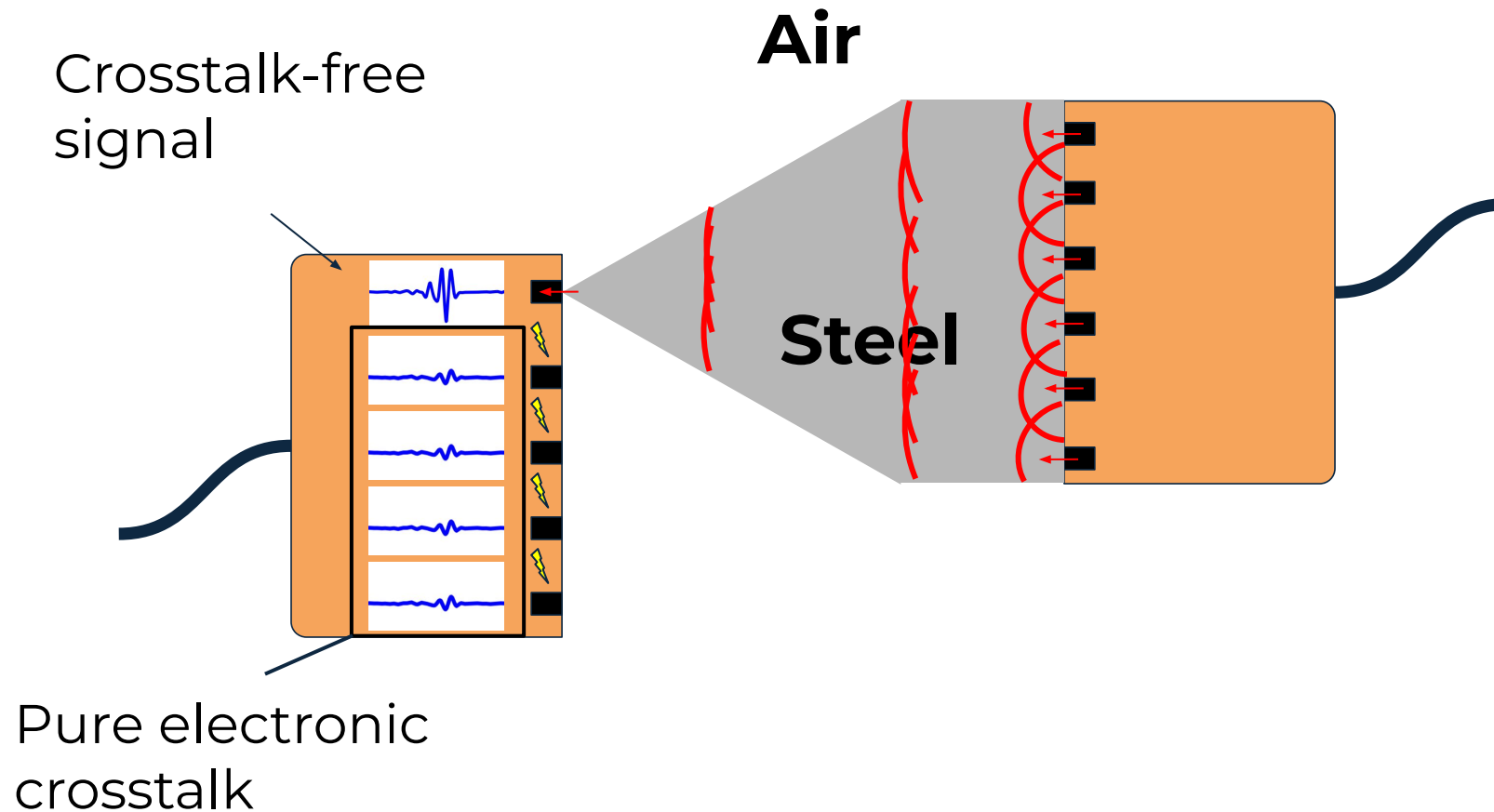
We had to made three main assumptions during modeling

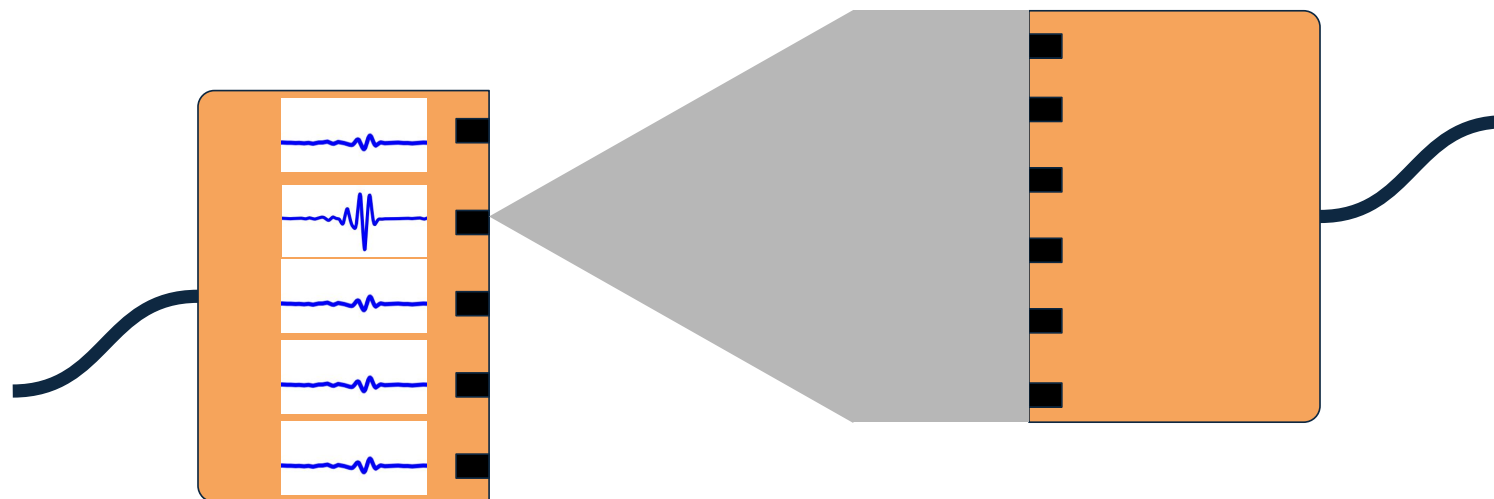
- 1. We can acquire somehow the ideal crosstalk-free signal for every element.**

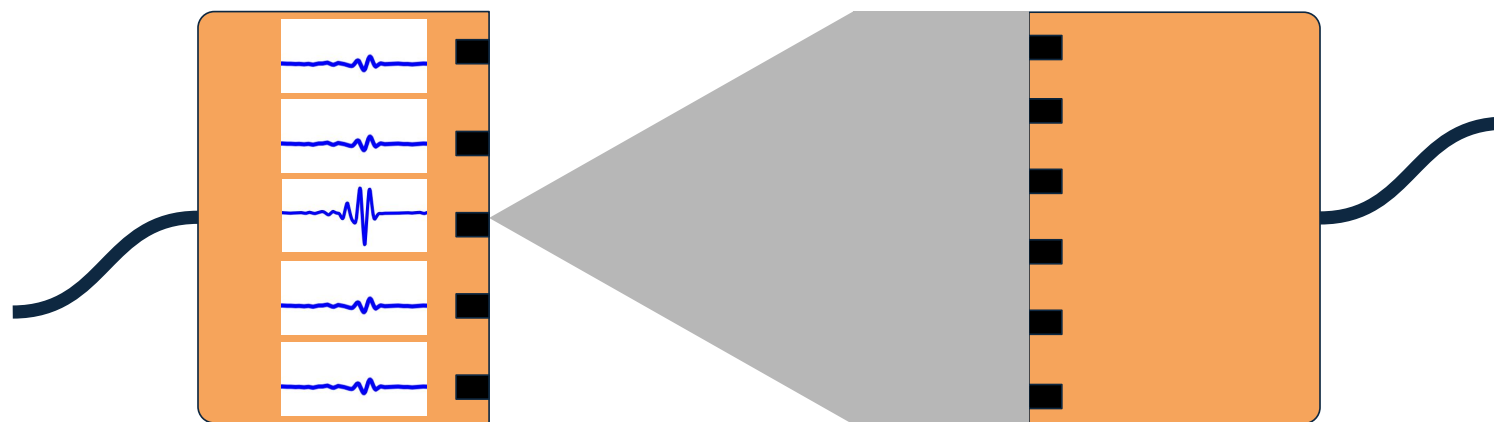
During modeling, we made a controlled experimental setup.



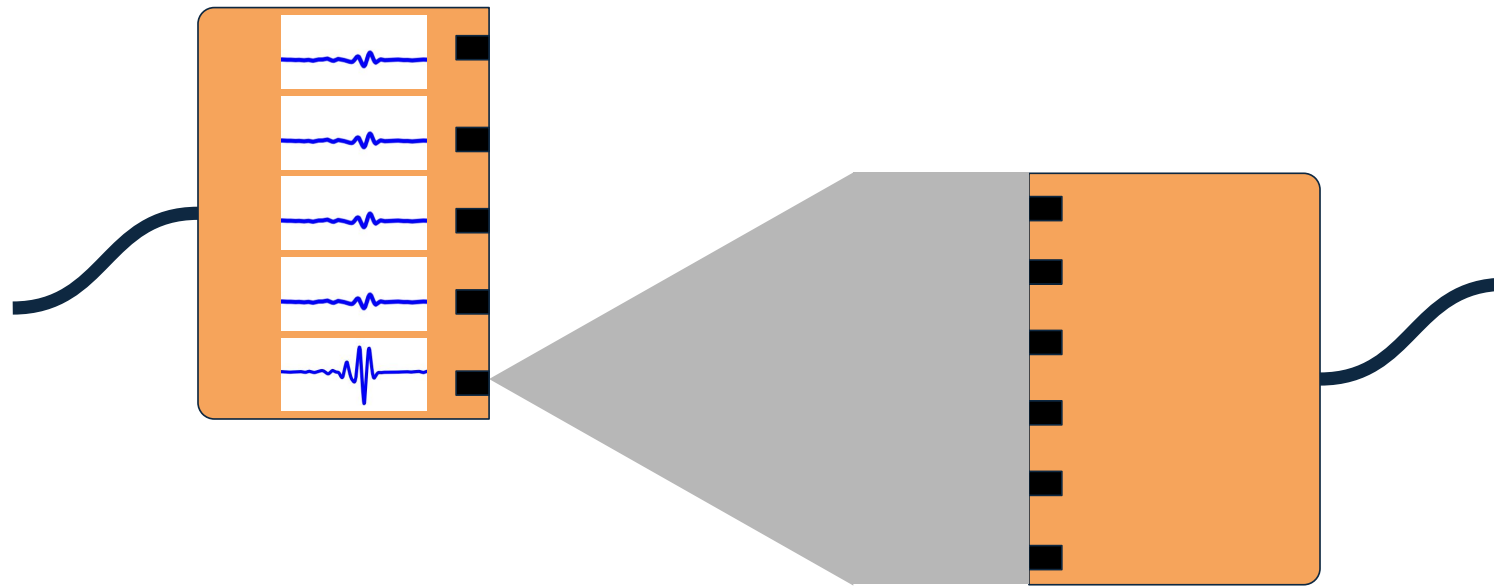
The goal of this experiment was to obtain a “pure” crosstalk signal.







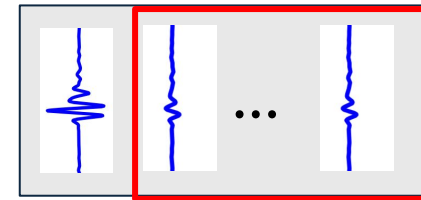
We repeated this procedure for every element, and the result was a set of Nel^2 signals.



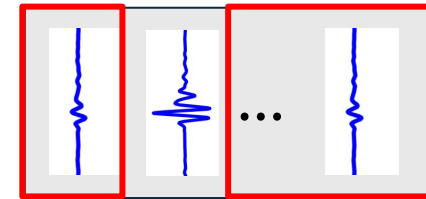
Let G_j be the contaminated cross-talk B-scan, and F_j the crosstalk-free B-scan:

$$j = 1$$

Measured G_j



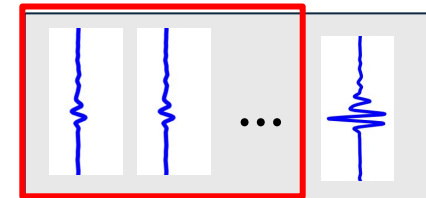
$$j = 2$$



Pure crosstalk

$\vdots$

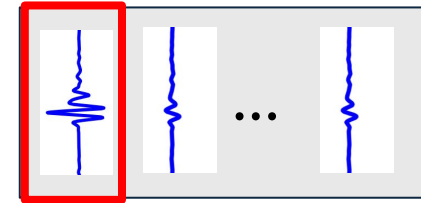
$$j = N_{el}$$



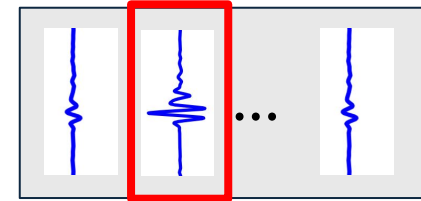
Let G_j be the contaminated cross-talk B-scan, and F_j the crosstalk-free B-scan:

$$j = 1$$

Measured G_j



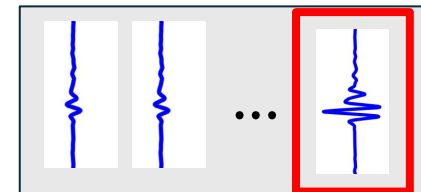
$$j = 2$$



Crosstalk-free

$\vdots$

$$j = N_{el}$$



We had to made three main assumptions during modeling

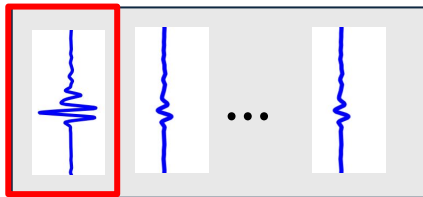
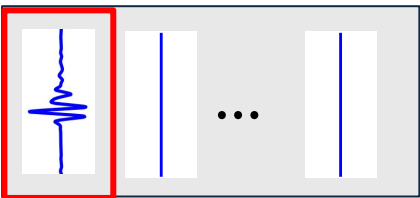
1. We can acquire somehow the ideal crosstalk-free signal for every element.
2. **During the controlled experiment the acquired signal is exactly equal to the crosstalk-free signal. The ideal signal does not have crosstalk.**

From this assumption, we can build F_j .

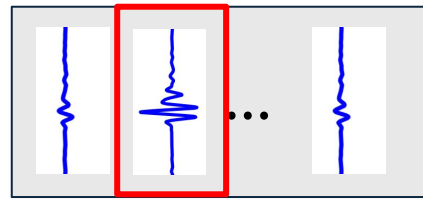
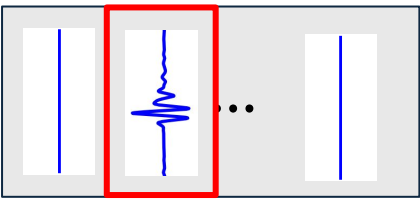
Ideal F_j

Measured G_j

$j = 1$



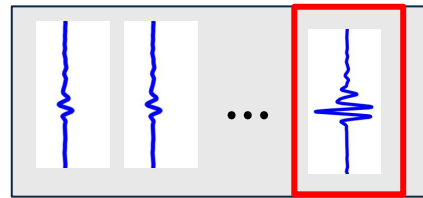
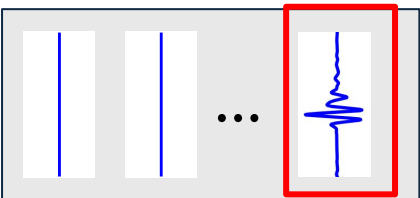
$j = 2$



Numerically
equal

$\vdots$

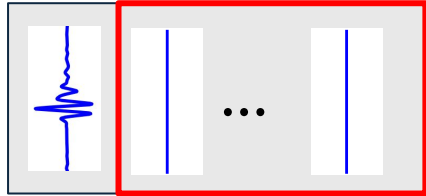
$j = N_{el}$



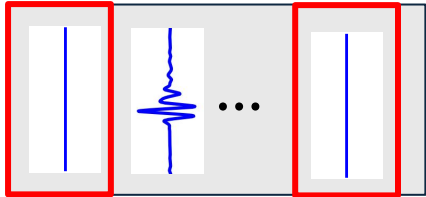
These are exactly equal to zero, since F_j does not have crosstalk.

Ideal F_j

$j = 1$

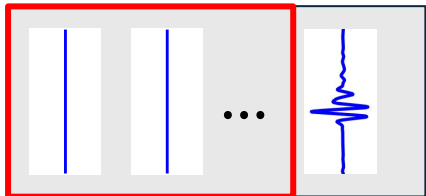


$j = 2$

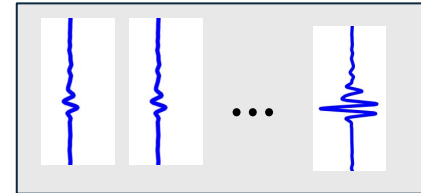
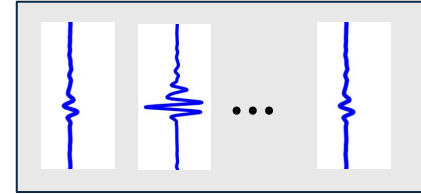
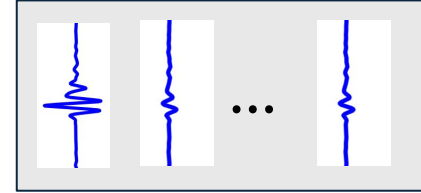


$\vdots$

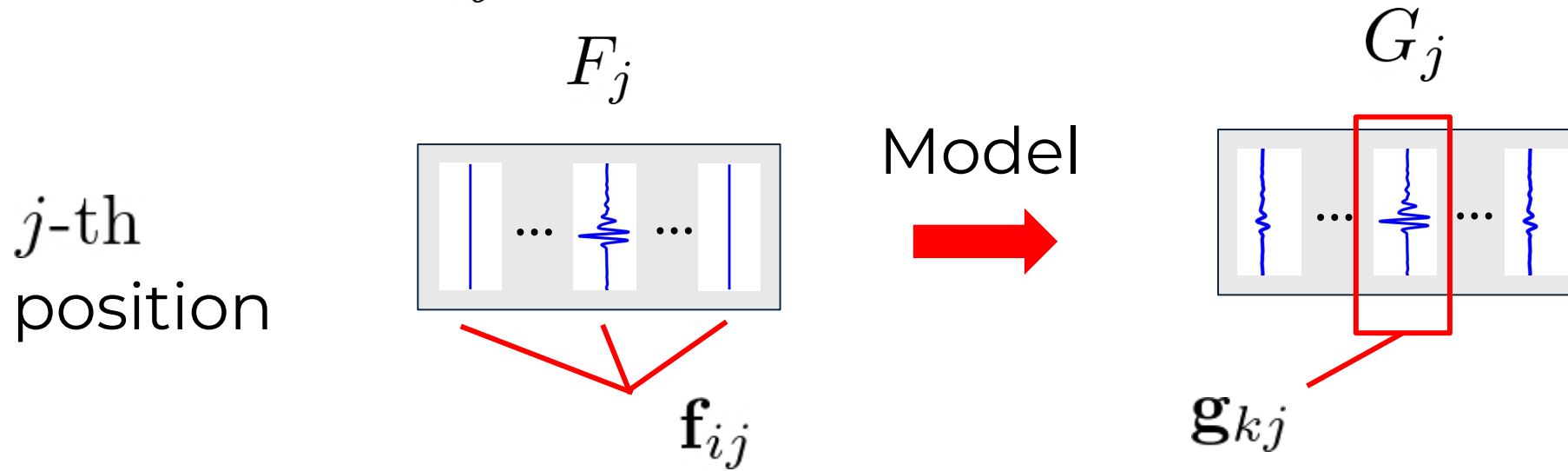
$j = N_{el}$



Measured G_j



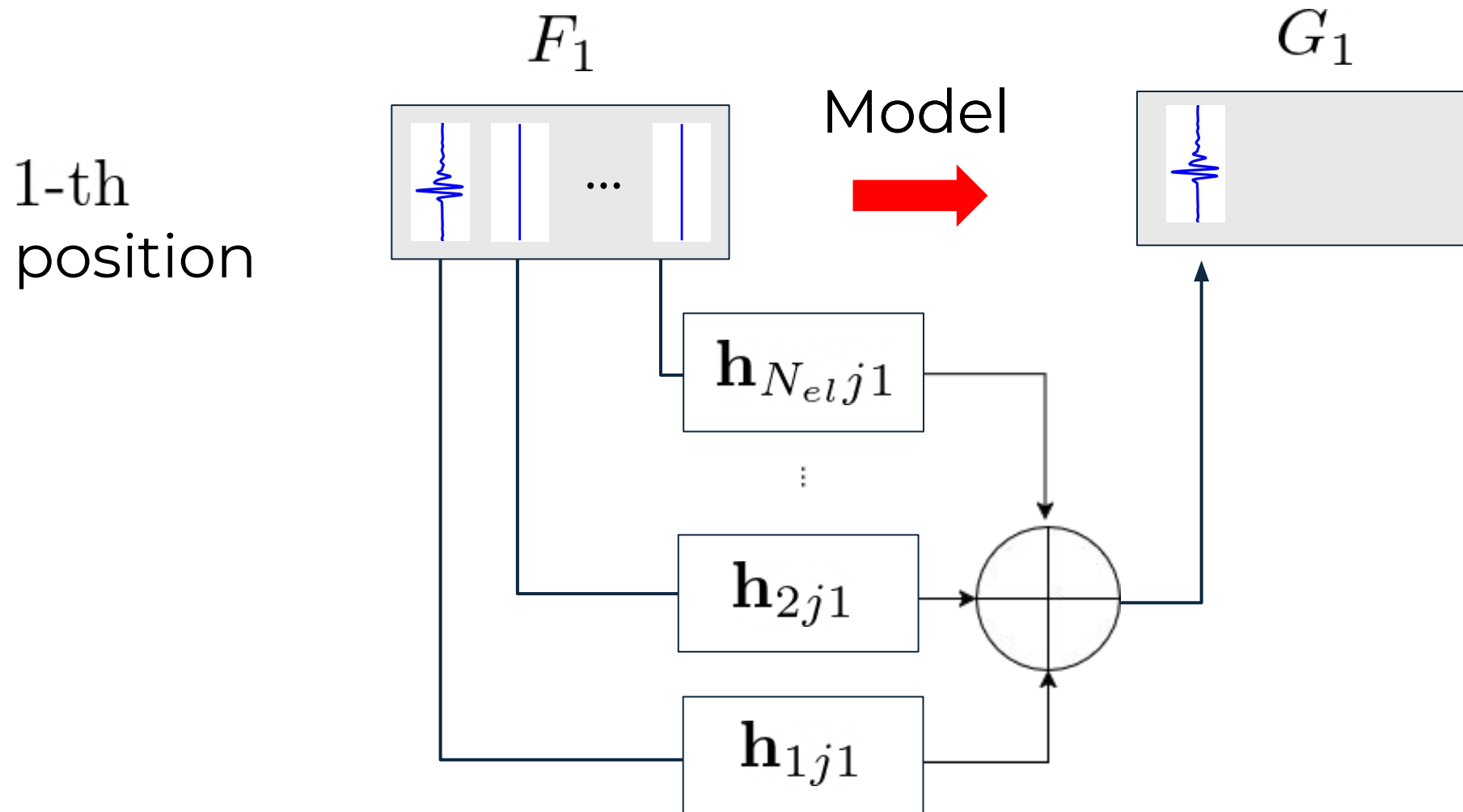
But still, there is missing a way to map the crosstalk-free signal F_j to G_j



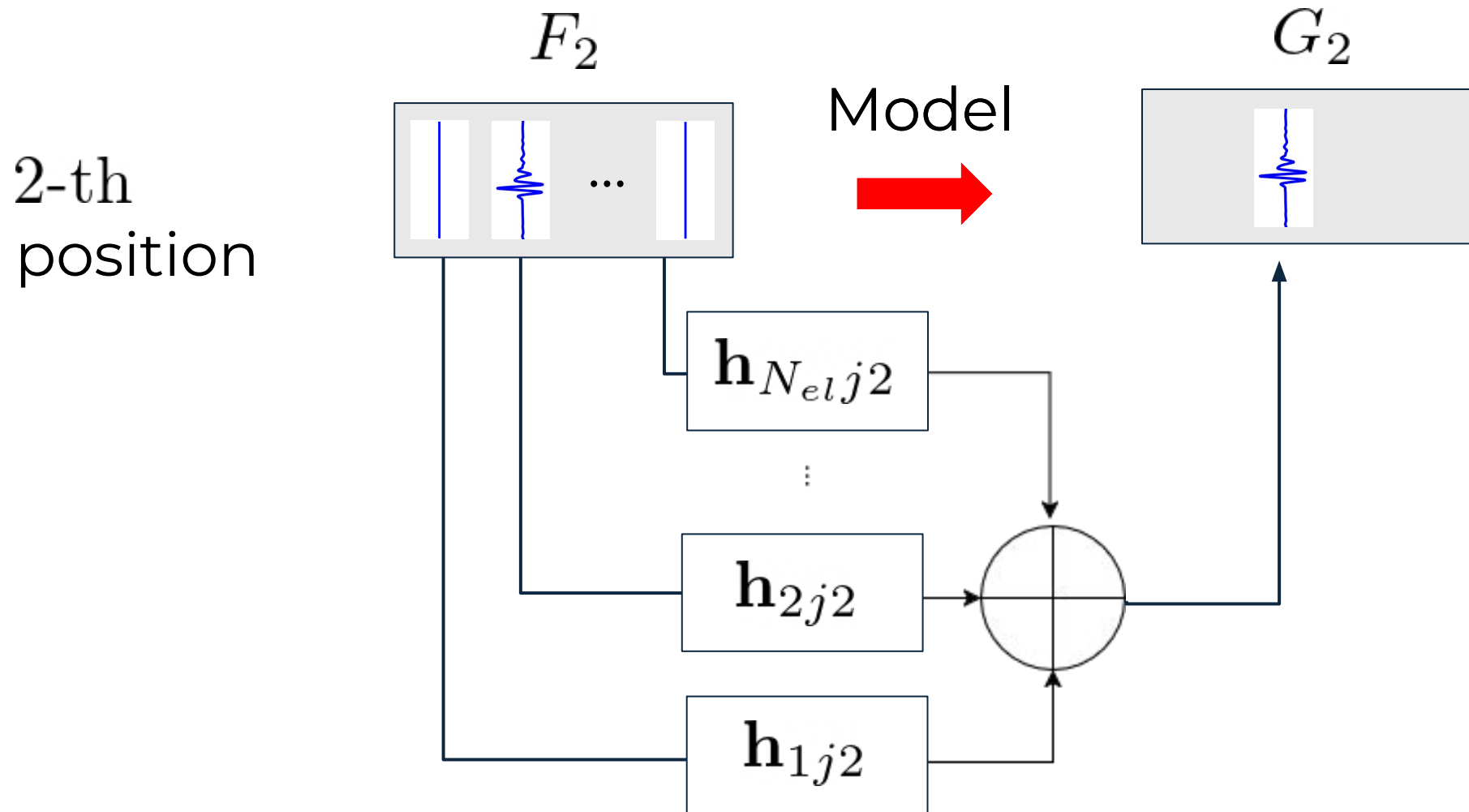
We had to made three main assumptions during modeling

1. We can acquire somehow the ideal crosstalk-free signal for every element.
2. During the controlled experiment the acquired signal is exactly equal to the crosstalk-free signal. The ideal signal does not have crosstalk.
- 3. The measured signal can be represented as the summation of the ideal signals convoluted by their respective impulse responses of the crosstalk.**

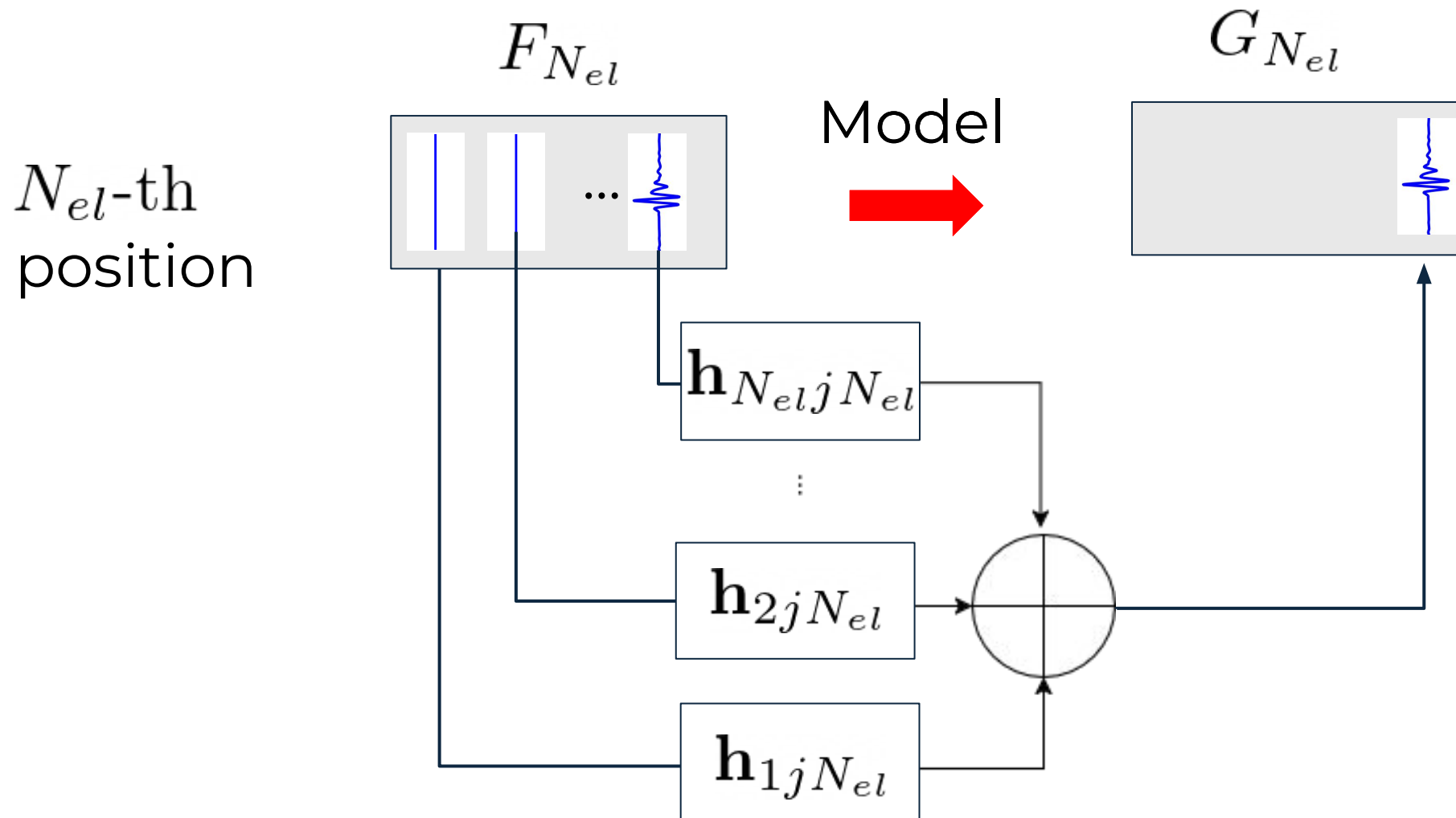
The last assumption let us write the measured signal as a superposition of crosstalk-free signal.



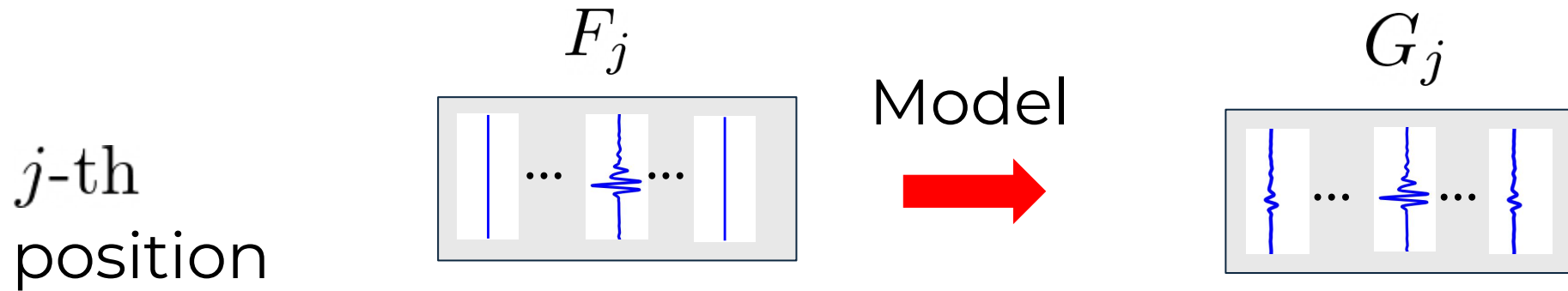
Which has an unique transfer function for each channel.



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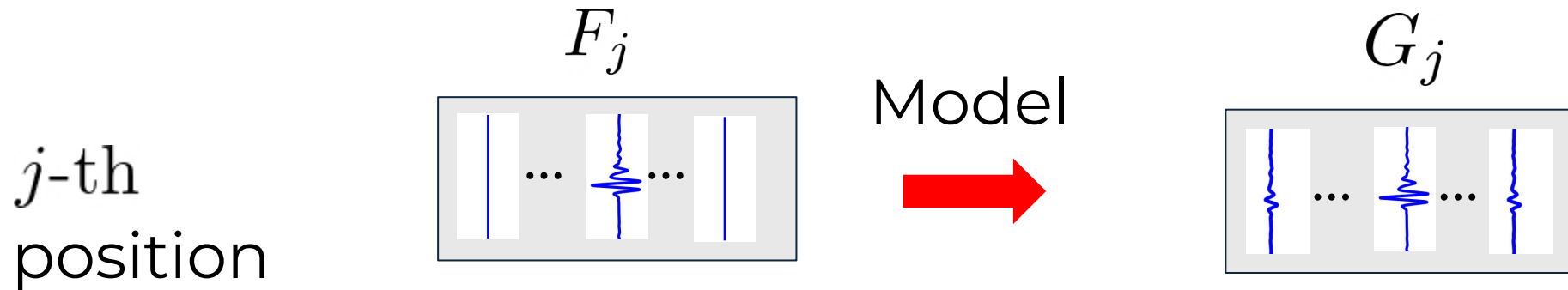


Which has the following mathematical notation.



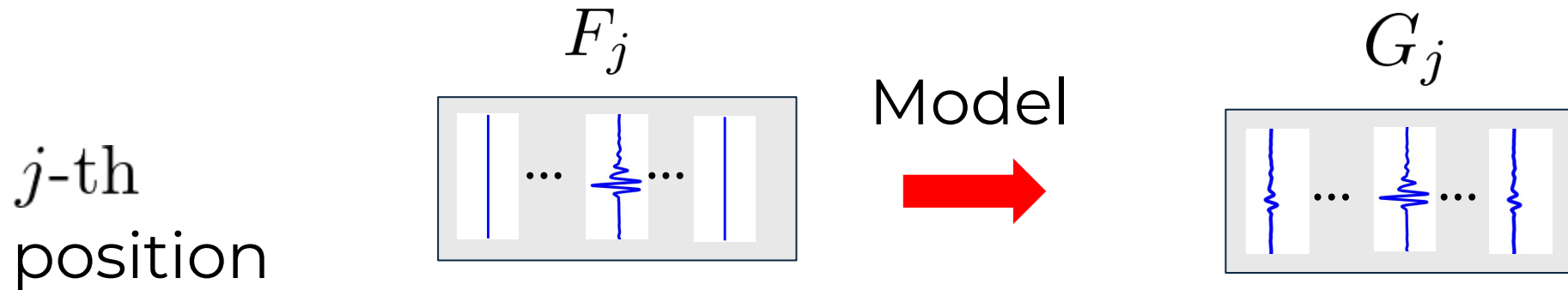
$$\mathbf{g}_{kj} = \sum_{i=1}^{N_{el}} \mathbf{f}_{ij} * \mathbf{h}_{ijk}$$

We assumed that the crosstalk-free signal is exactly the measured signal at the calibration positions and **zero otherwise**



$$\mathbf{f}_{ij} \approx \begin{cases} \mathbf{g}_{jj} & i = j \\ \mathbf{0} & i \neq j \end{cases}$$

Since we know the structure of the crosstalk-free signal, we can simplify this equation, yielding:



$$\mathbf{g}_{kj} = \mathbf{f}_{jj} * \mathbf{h}_{jk}$$

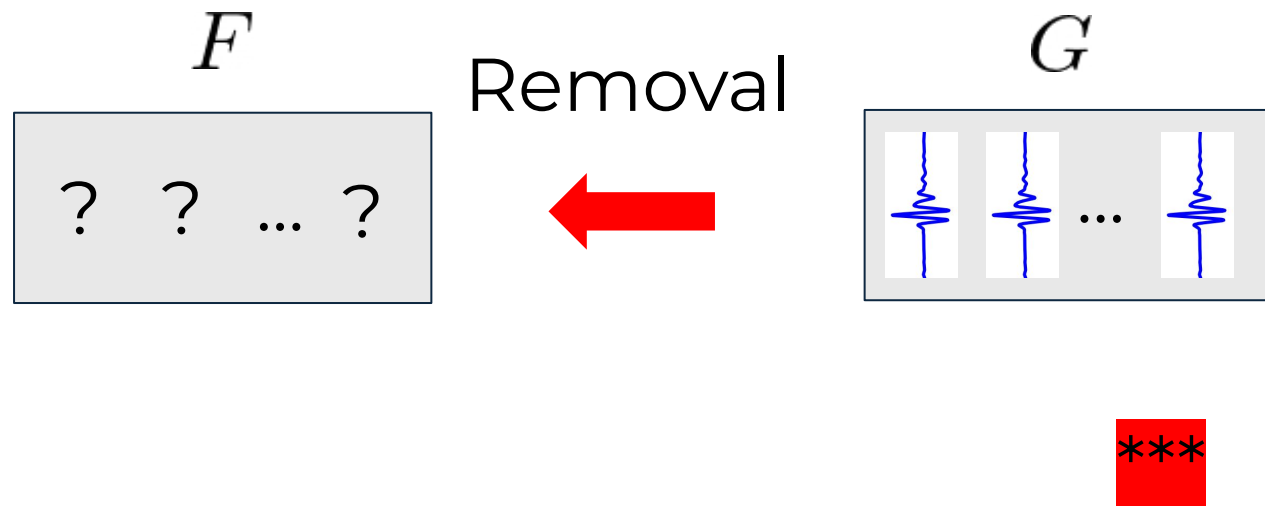
Given those assumptions, we can represent the crosstalk as a linear time-invariant system given by

$$\mathbf{g}_{kj} = \mathbf{f}_{jj} * \mathbf{h}_{jk}$$

$$\mathbf{f}_{jj} * \mathbf{h}_{jk} - \mathbf{g}_{kj} = 0$$

$$\mathbf{h}_{jk} \approx \arg \min_{\hat{\mathbf{h}}_{jk}} \left\| \mathbf{f}_{jj} * \hat{\mathbf{h}}_{jk} - \mathbf{g}_{kj} \right\|_2$$

After modeling we know the crosstalk transfer function, but we don't know the crosstalk-free signal G



Given those assumptions, we can represent the crosstalk as a linear time-invariant system given by

$$\mathbf{g}_k = \sum_{j=1}^{N_{el}} \mathbf{h}_{jk} * \mathbf{f}_j$$

$$\mathcal{H}(F) = G$$

$$F \approx \arg \min_{\hat{F}} \left\| \mathcal{H}(\hat{F}) - G \right\|_2$$

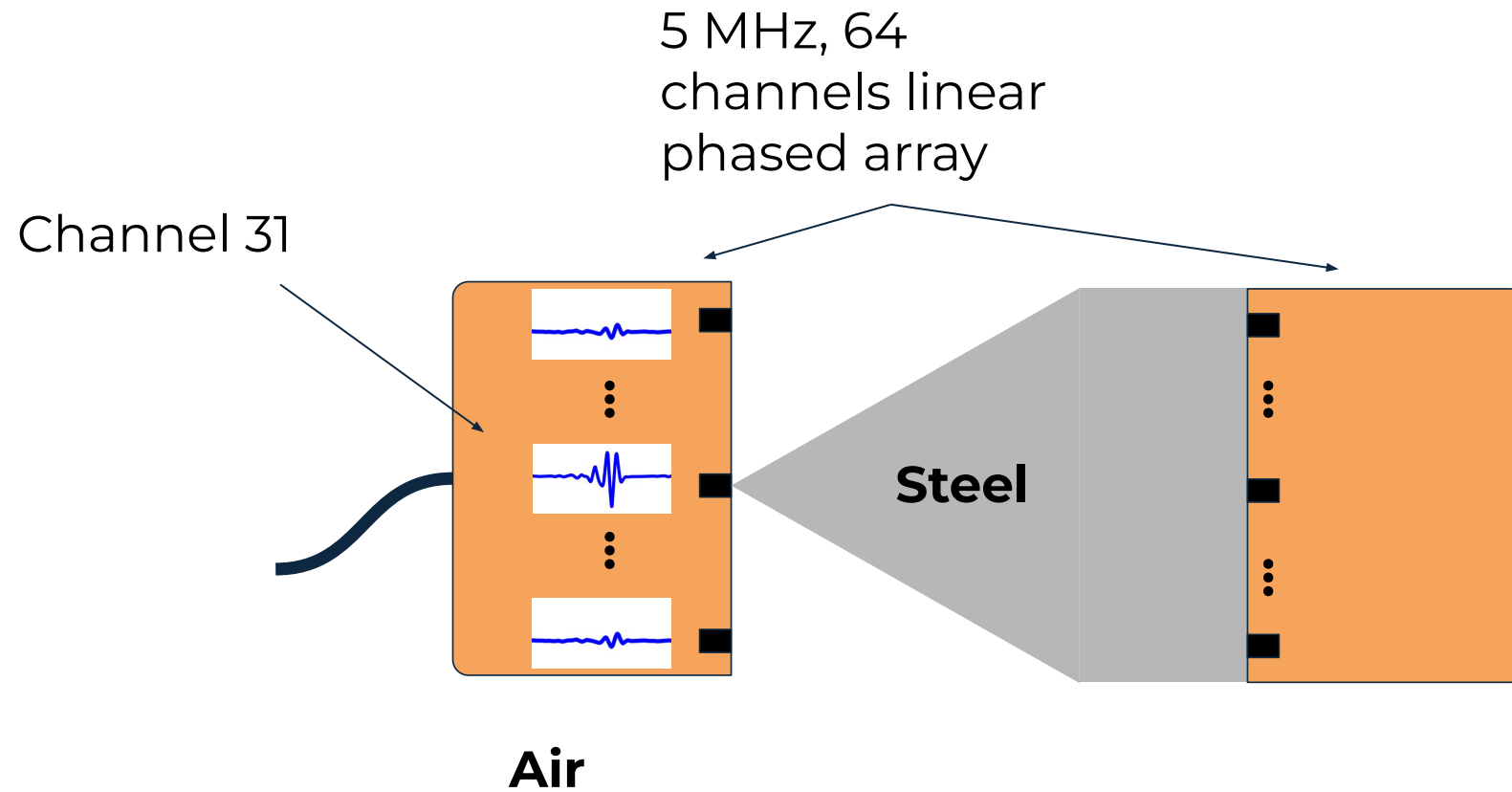
Both stages goes through the same cost-function, but with a different independent variable.

Modeling:
$$\mathbf{h}_{jk} \approx \arg \min_{\hat{\mathbf{h}}_{jk}} \left\| \mathbf{f}_{jj} * \hat{\mathbf{h}}_{jk} - \mathbf{g}_{kj} \right\|_2$$

Removal:
$$F \approx \arg \min_{\hat{F}} \left\| \mathcal{H} \left(\hat{F} \right) - G \right\|_2$$

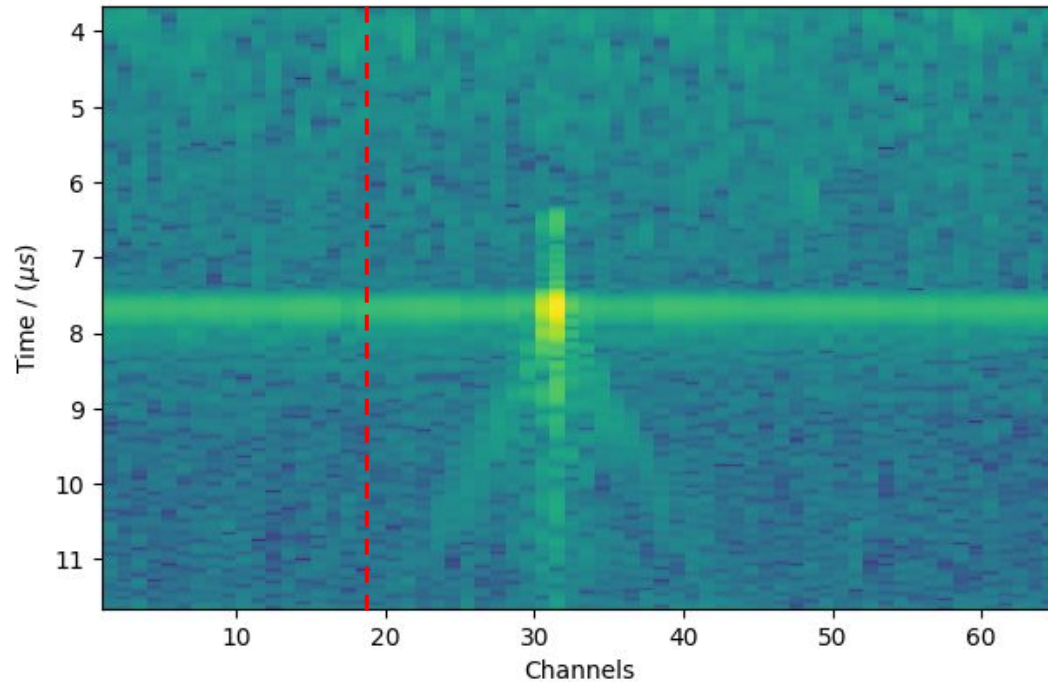
Results

Experiment 1: synthesize crosstalk from the controlled experiment.

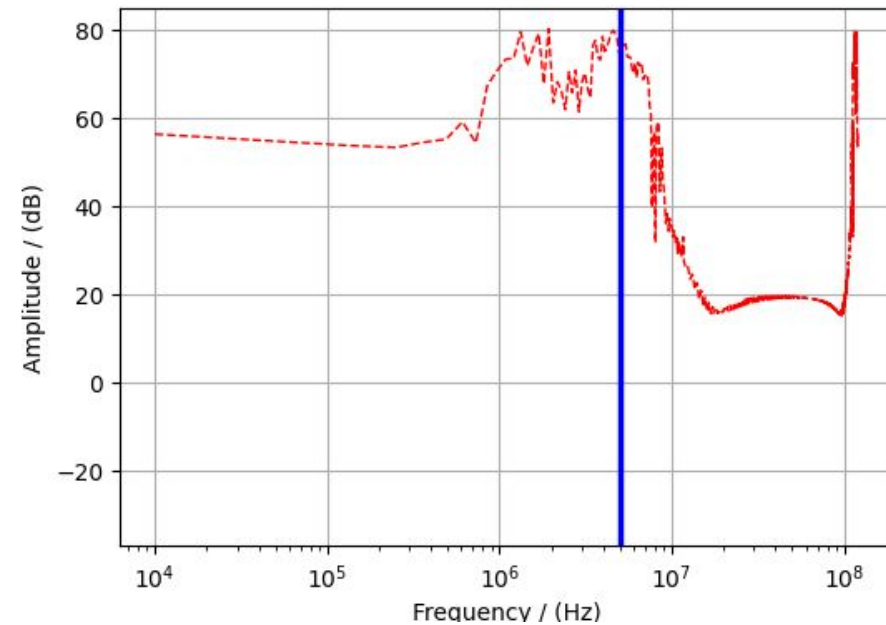


Theoretically, only one channel had to contain signal, but crosstalk spreads across the others.

B-scan

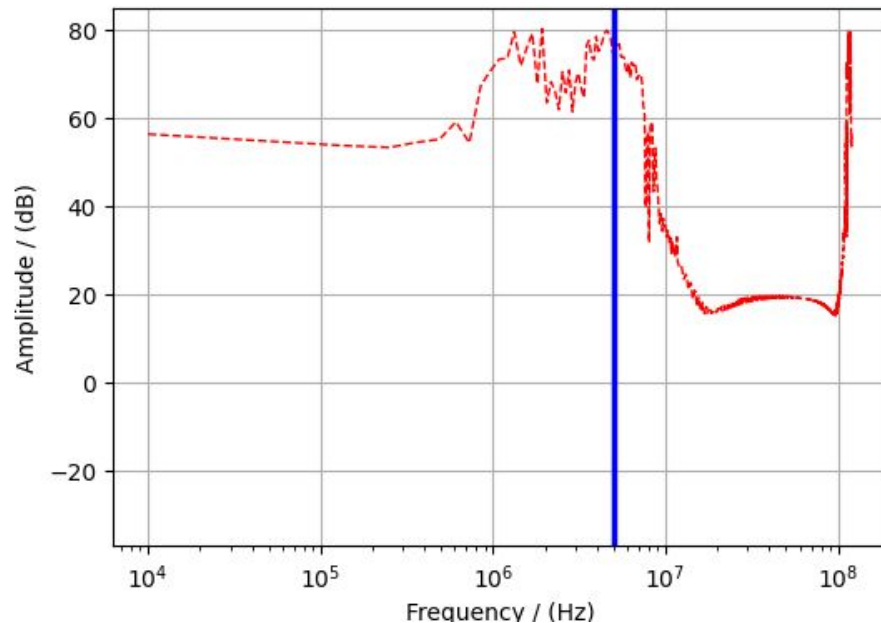


Magnitude of the Spectrum of the **18th** channel.

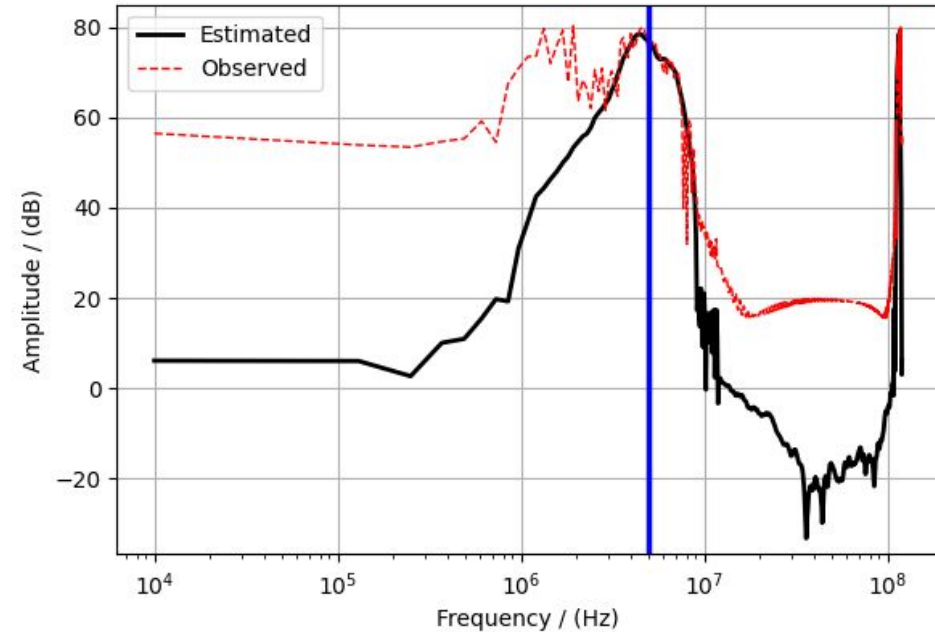


We can interpret the synthesis as a band-pass filter adapted to the excitation signal.

Observed Magnitude of Spectrum

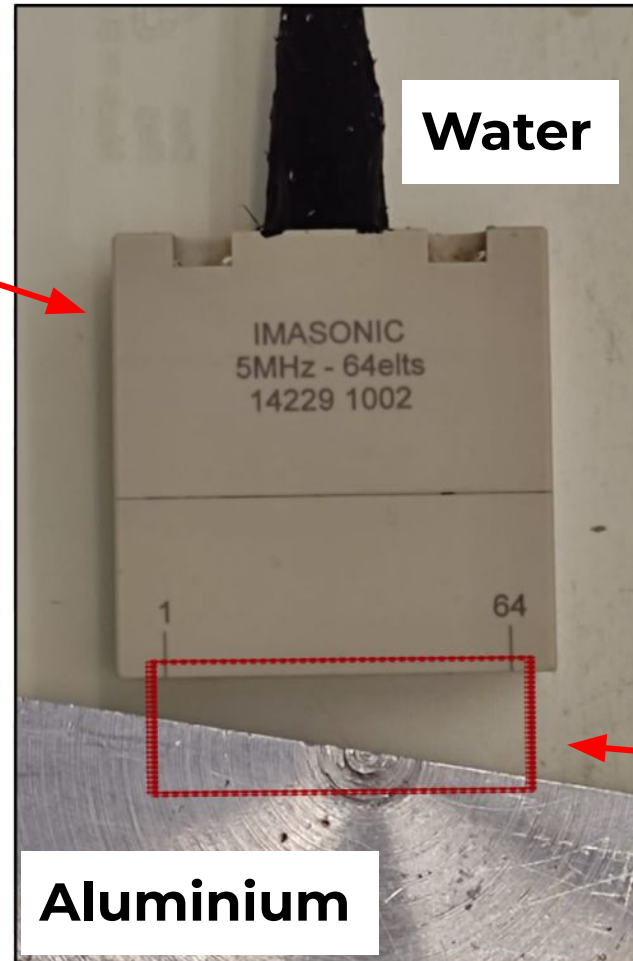


Estimated Magnitude of Spectrum



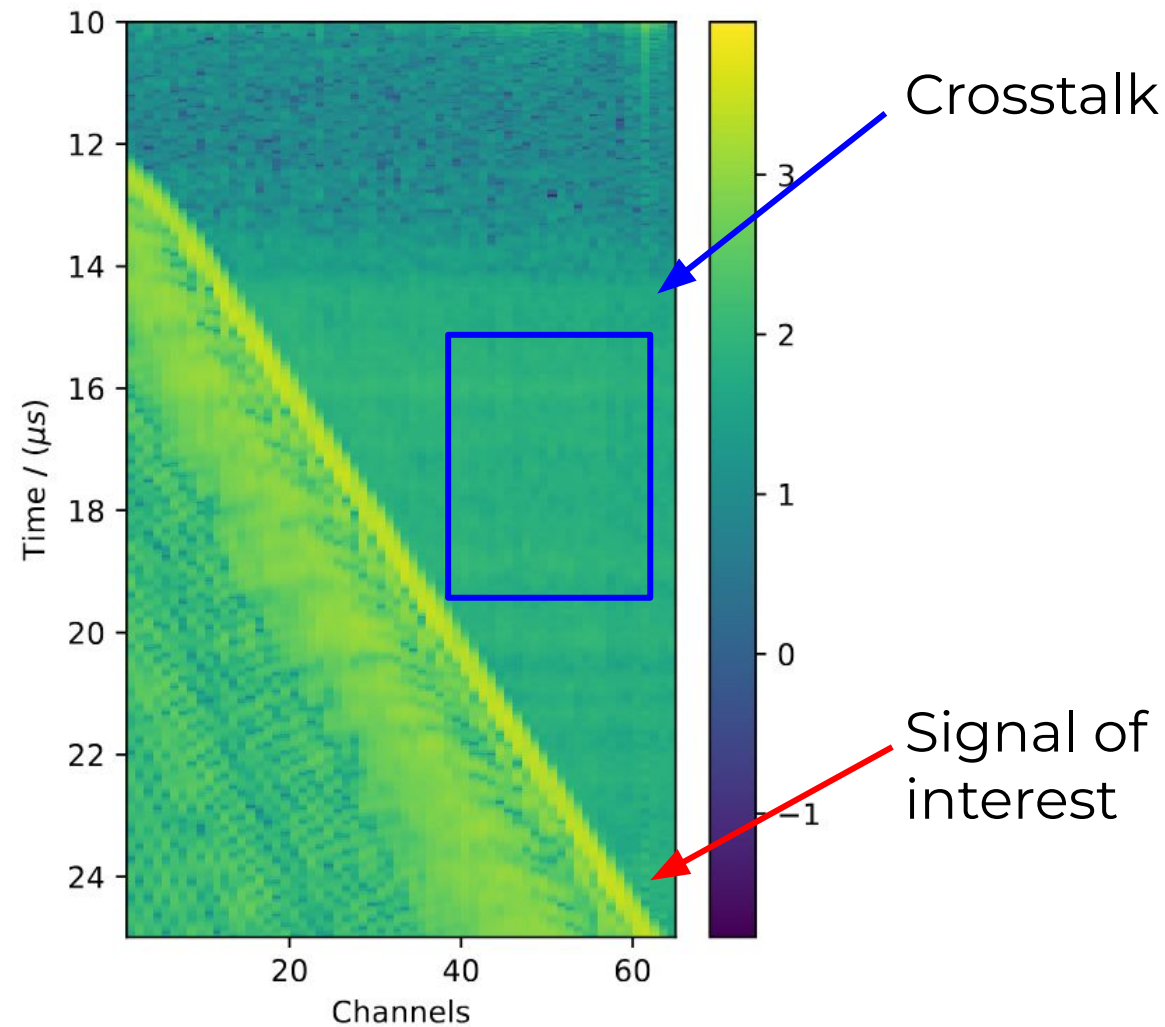
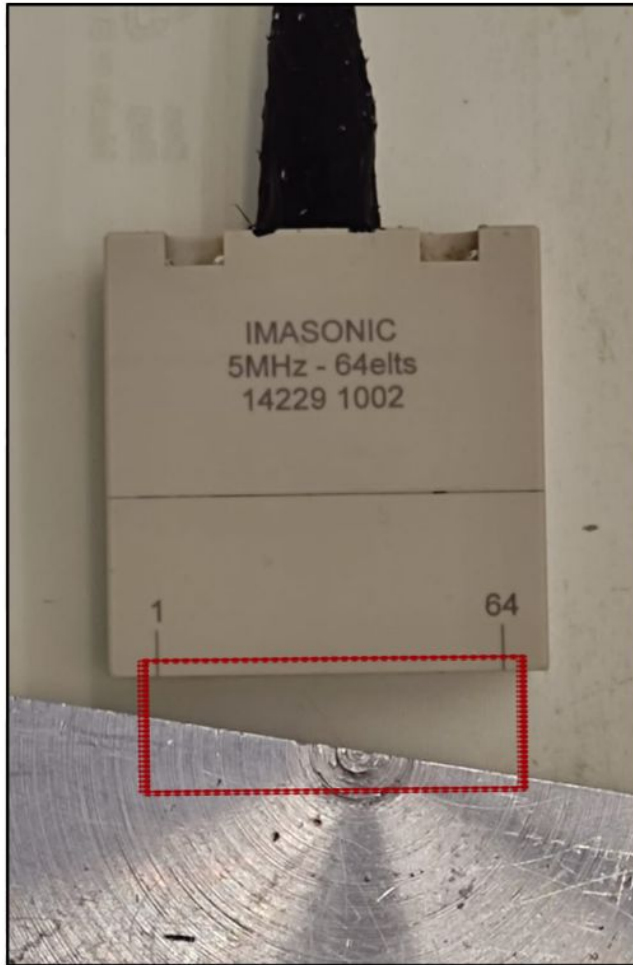
Experiment 2: immersion inspection of a rectangular specimen

5 MHz, 64
channels linear
phased array

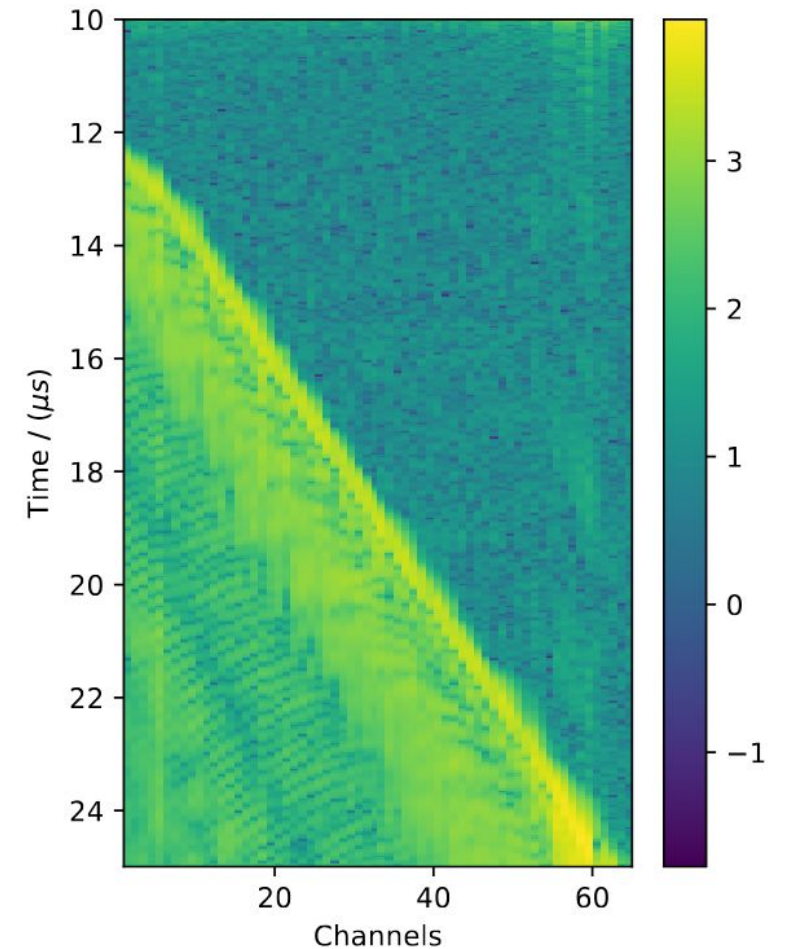
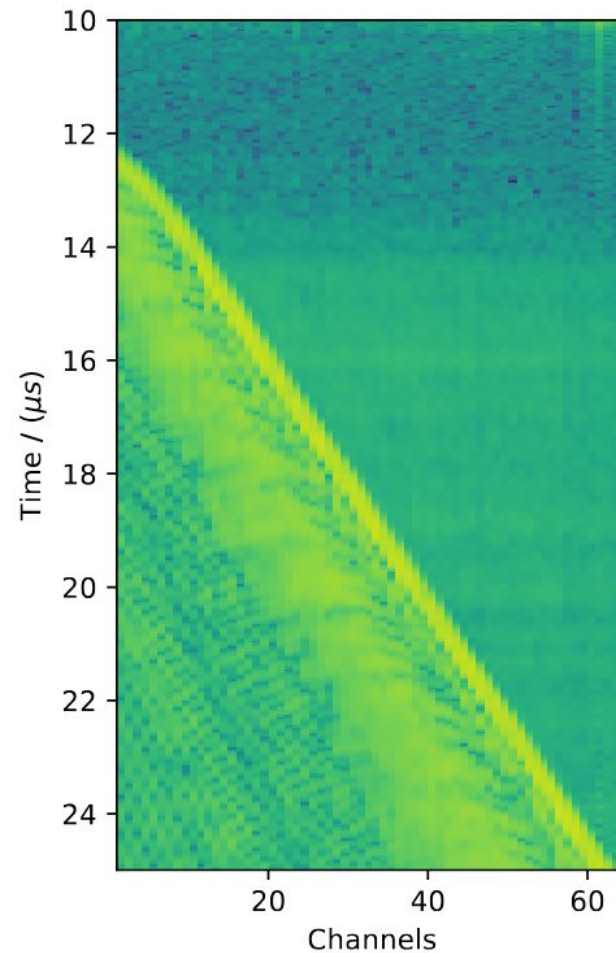
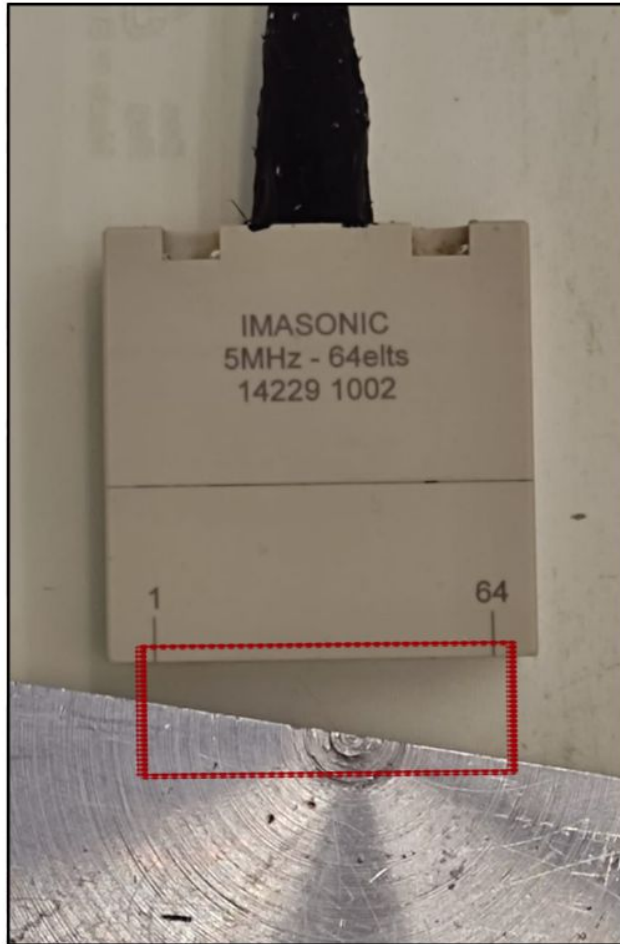


Region of
interest

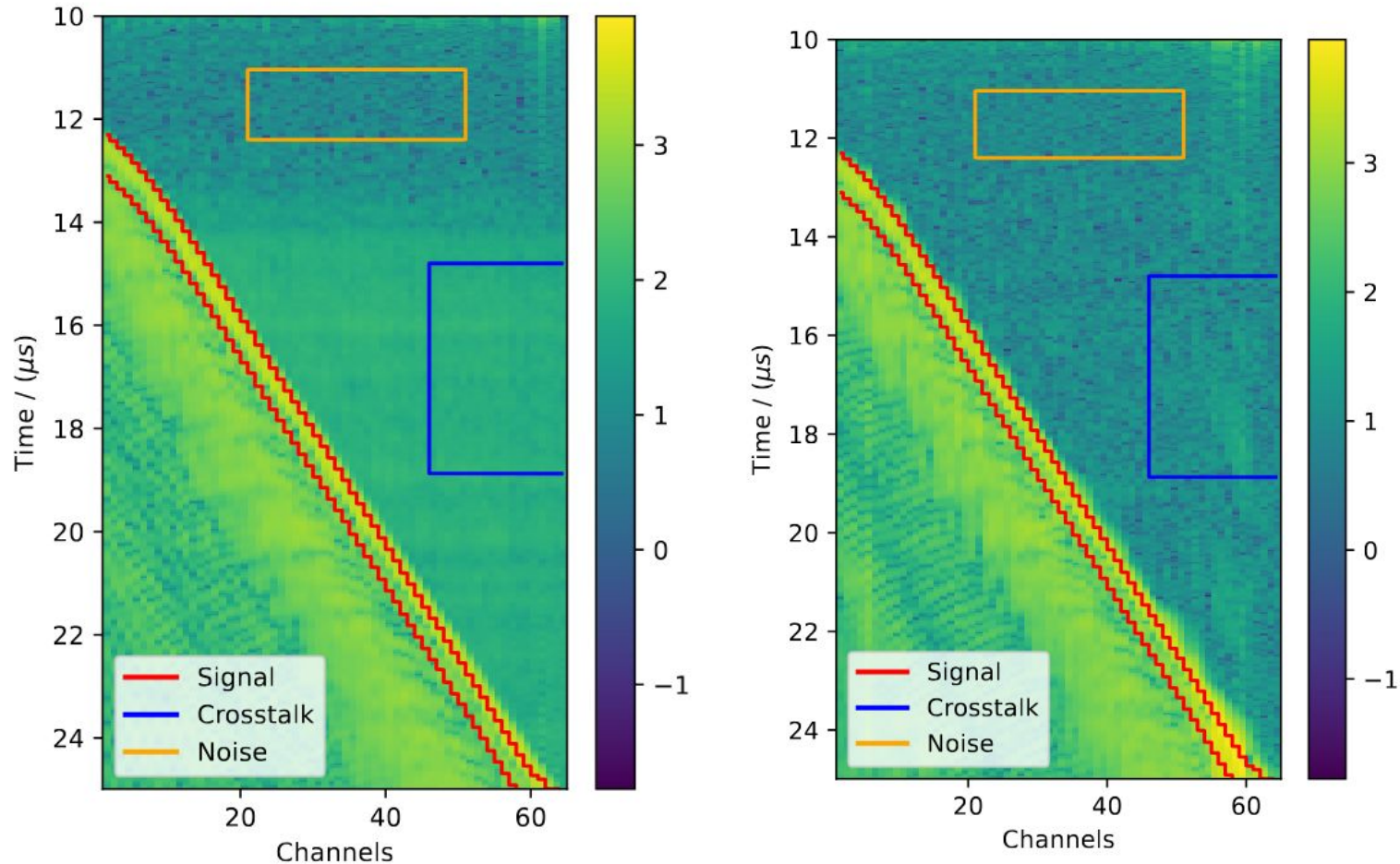
The received channels show significant amount of crosstalk.



Since we have already modeled the crosstalk for this probe, we just applied the removal.



We defined spatial windows to extract signal of interest, noise and crosstalk values.



We computed three metrics for this case to evaluate the model quantitatively.

$$\text{SINR} = \frac{\|\mathcal{S}\|_2}{\|\mathcal{C}\|_2 + \|\mathcal{M}\|_2}, \quad \text{CNR} = \frac{|\mu_{\mathcal{S}} - \mu_{\mathcal{C}}|}{\sigma_{\mathcal{C}}}, \quad \text{CR} = \frac{\mu_{\mathcal{S}}}{\mu_{\mathcal{C}}}.$$

where $\mathcal{S}$, $\mathcal{C}$ and $\mathcal{M}$ are the regions corresponding to the signal, the crosstalk and the noise, respectively.

We computed three metrics for this case to evaluate the model quantitatively.

Metrics	Original B-scan	Post-Removal B-scan	Δ
SINR	29.2 dB	42.6 dB	13.4 dB
CNR	27.8 dB	39.7 dB	11.9 dB
CR	47.3 dB	55.4 dB	8.1 dB

**At least an 8 dB
improvement!**



Conclusions

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- **Our model successfully removed electronic crosstalk, by modeling this phenomenon through a controlled experiment.**

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- **Huge quantitative improvement, i.e. at least 8 dB or 150 %.**

Conclusion

- Our model successfully removed electronic crosstalk, by modeling this phenomenon through a controlled experiment.
- The removal acts as a band-pass filter automatically projected based on the controlled experiment.
- Huge quantitative improvement, i.e. at least 8 dB or 150 %.
- **Our methodology could be part of a data processing pipeline especially on deep sea pipe inspections where extra adaptors must be used.**

Acknowledgements

Thanks to

- UTFPR
- Petróleo Brasileiro S.A. (Petrobras)
- ANP / PRH-21.1
- Fundação Araucária
- CAPES



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EUROPEAN CONFERENCE ON NON-DESTRUCTIVE TESTING

Thank you!

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Laboratory for Statistical Signal Processing and Inverse
Problems (LASSIP)*

