TU1C-1

Cancellation of Air-Induced Passive Intermodulation in FDD MIMO Systems: Low-Complexity Cascade Model and Measurements

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1. Introduction

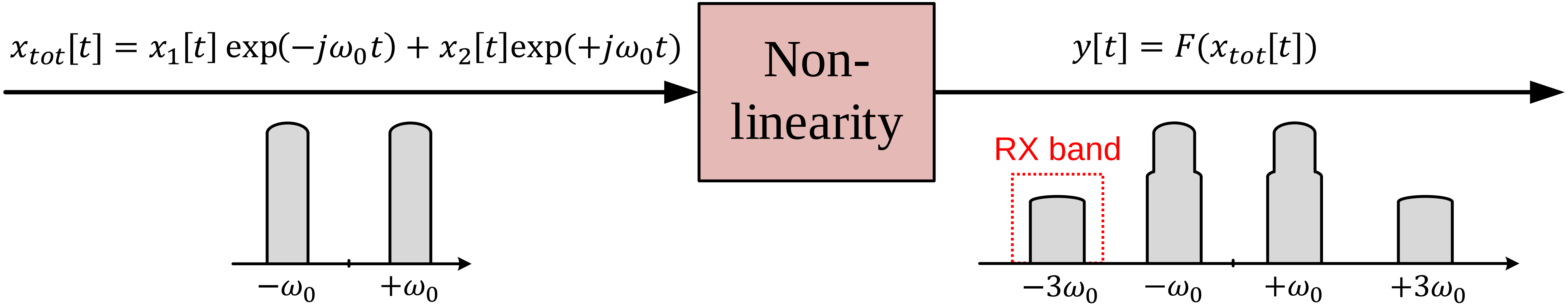
- BSs deployed in various environments
- Carrier aggregation (CA) in 5G
- Nearby objects can
  1. Reflect the TX signal
  2. Apply nonlinear distortion

➢ *Air-induced passive intermodulation (PIM)*

Figure source: https://research.tuni.fi/wireless/infrastructures/

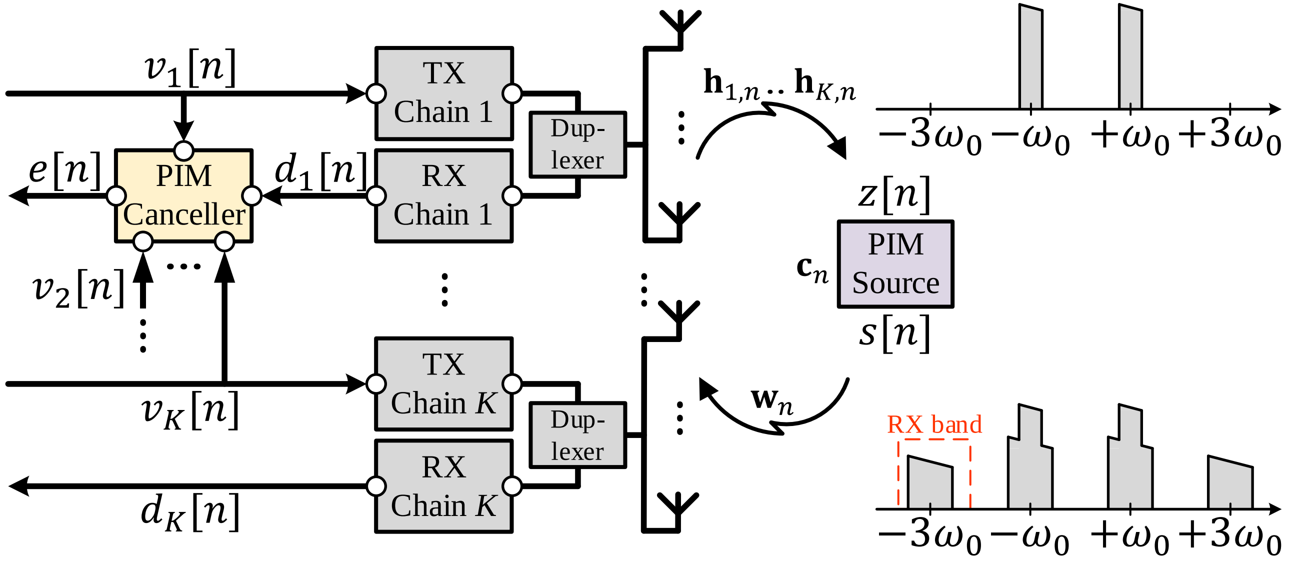
1. Introduction

- Intermodulation stems from nonlinear systems
- PIM from passive devices
- Possibly an issue in FDD systems



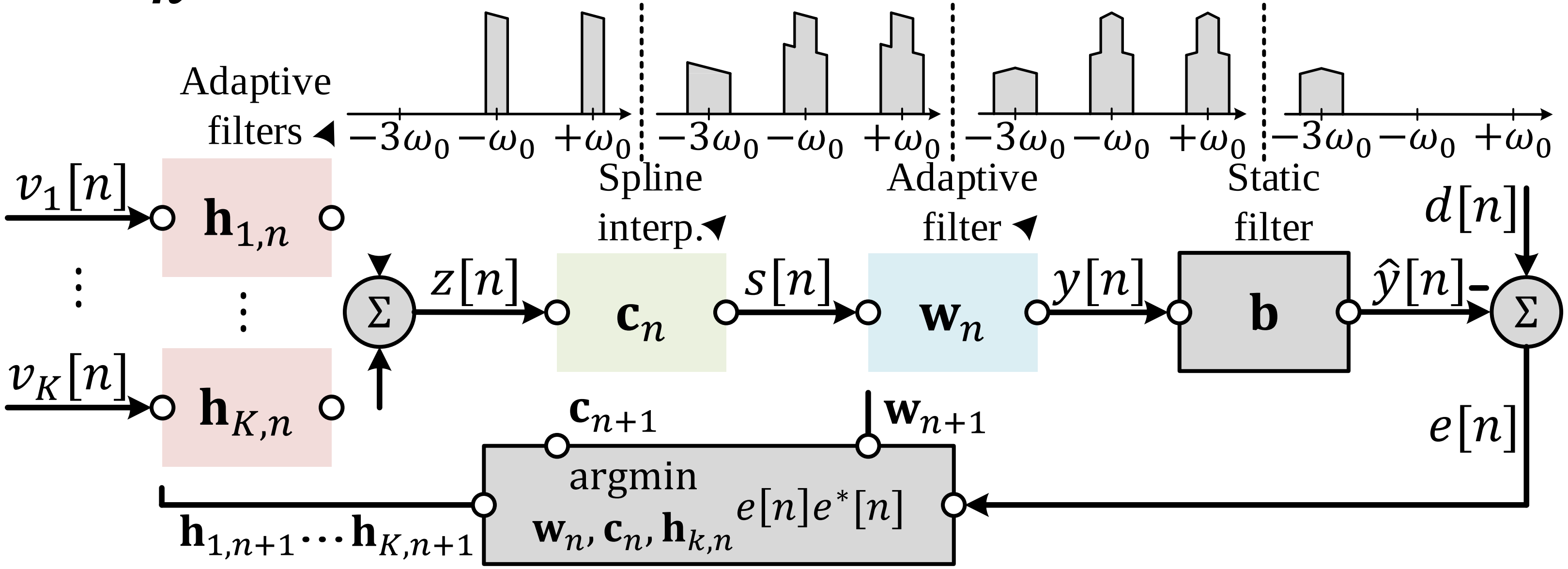
2. System Model

- K parallel TX/RX chains transmit aggregated signals $v_k[n]$
- Signals propagate though channels $\mathbf{h}_n$ to PIM source input
- Nonlinear distortion in PIM source
- Interfering signals $d[n]$ received after channel $\mathbf{w}_n$



3. Proposed Method

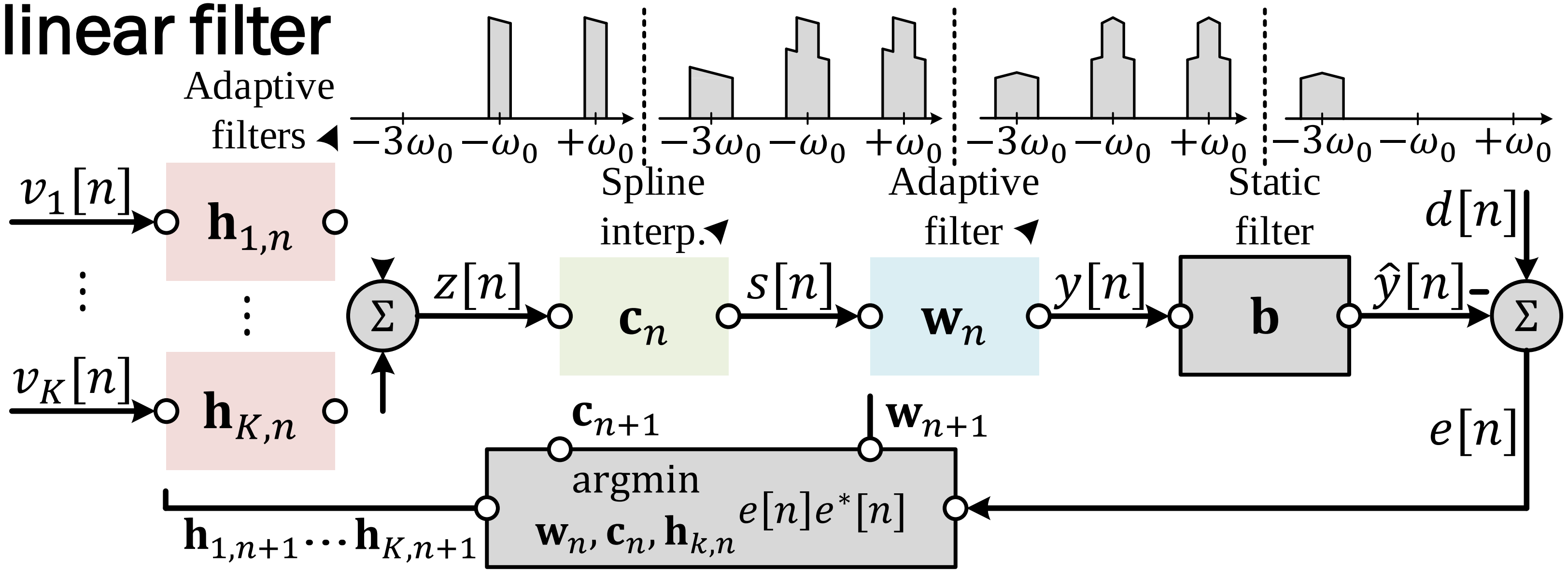
- Generate distortion estimate $\hat{y}[n]$ and subtract from $d[n]$
- Employ below cascade model:
  - Adaptive filters $\mathbf{h}_{1,n}$, ..., $\mathbf{h}_{K,n}$, $\mathbf{w}_n$
  - Static filter $\mathbf{b}$
  - Spline-interpolated LUT $\mathbf{c}_n$



3. Proposed Method

- Main Path:
  - $z[n] = \sum_{k=1}^{K} \mathbf{h}_{k,n}^{T} \mathbf{v}_{k,n}$, sum of adaptive linear filter outputs
  - $s[n] = z[n]\left(1 + \boldsymbol{\Psi}_n^T \mathbf{c}_n\right)$, spline interpolation
  - $y[n] = \mathbf{w}_n^T \mathbf{s}_n$, adaptive linear filter
  - $\hat{y}[n] = \mathbf{b}^T \mathbf{y}_n$, static linear filter

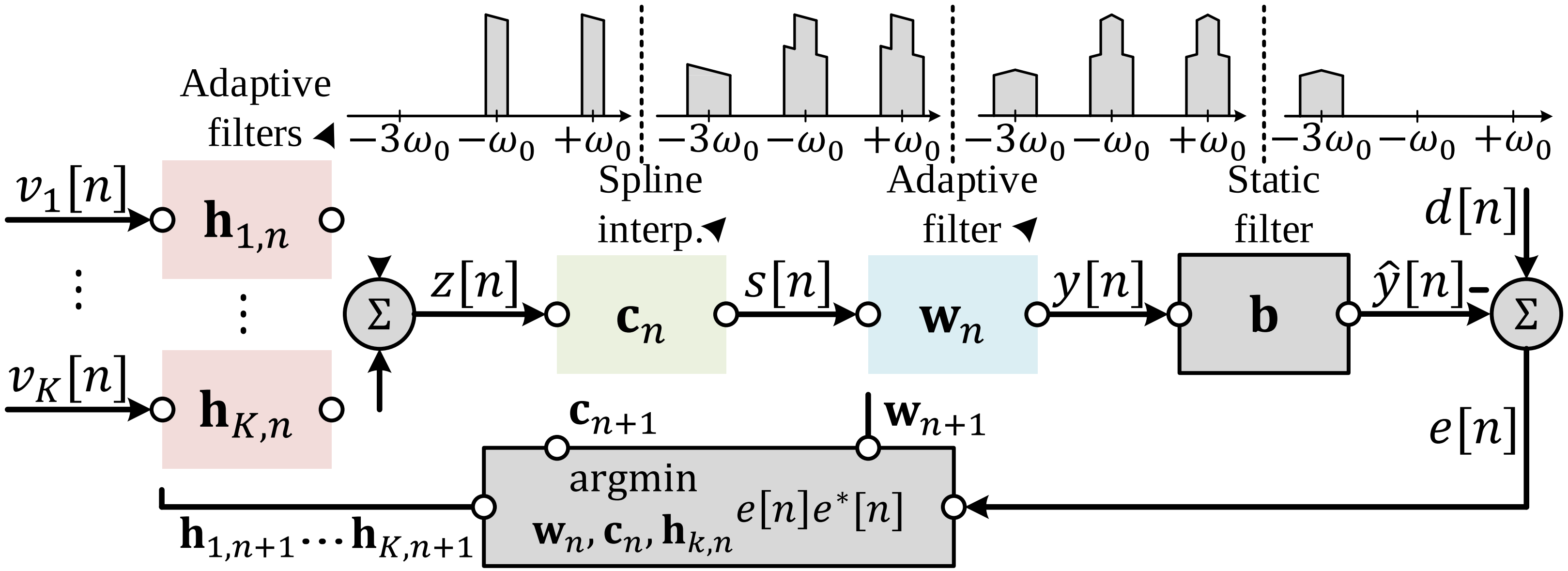
$\mathbf{v}_{k,n}$, $\mathbf{s}_n$, and $\mathbf{y}_n$ collect past samples of $v_k[n]$, $s[n]$, and $y[n]$, respectively



3. Proposed Method

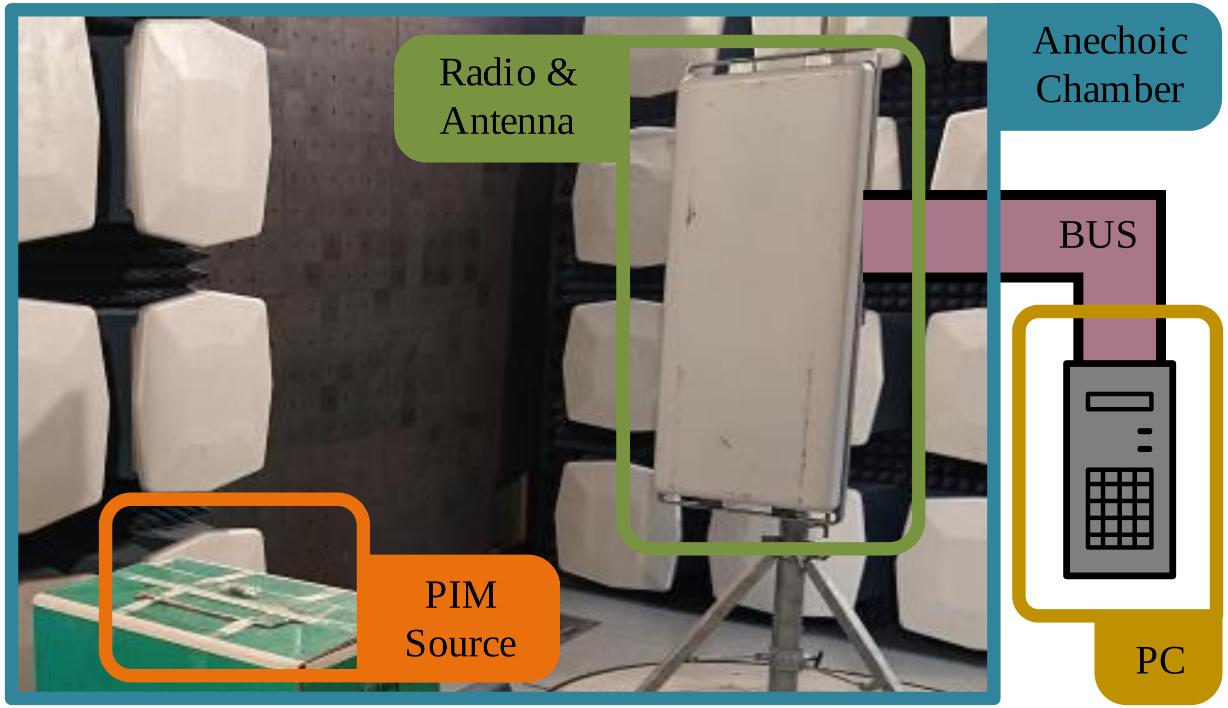
- Low complexity parameter adaptation with gradient descent:
  - $\mathbf{w}_{n+1} = \mathbf{w}_n + \mu_w e[n] \mathbf{S}_n^* \mathbf{b}$
  - $\mathbf{c}_{n+1} = \mathbf{c}_n + \mu_c e[n] \mathbf{\Pi}_n^* \mathbf{b}$
  - $\mathbf{h}_{k,n+1} = \mathbf{h}_{k,n} + \mu_h e[n] \mathbf{\Xi}_{k,n}^* \mathbf{b}$

Definitions of S_n, Π_n, and Ξ_n omitted for brevity



4. Measurements & Results

- Measurements in anechoic chamber
- Steel wool as PIM source
- TX: 1819 MHz and 1866.5 MHz (n3)
- RX: 1771.5 MHz (n3)
- TX power at 31 dBm



4. Measurements & Results

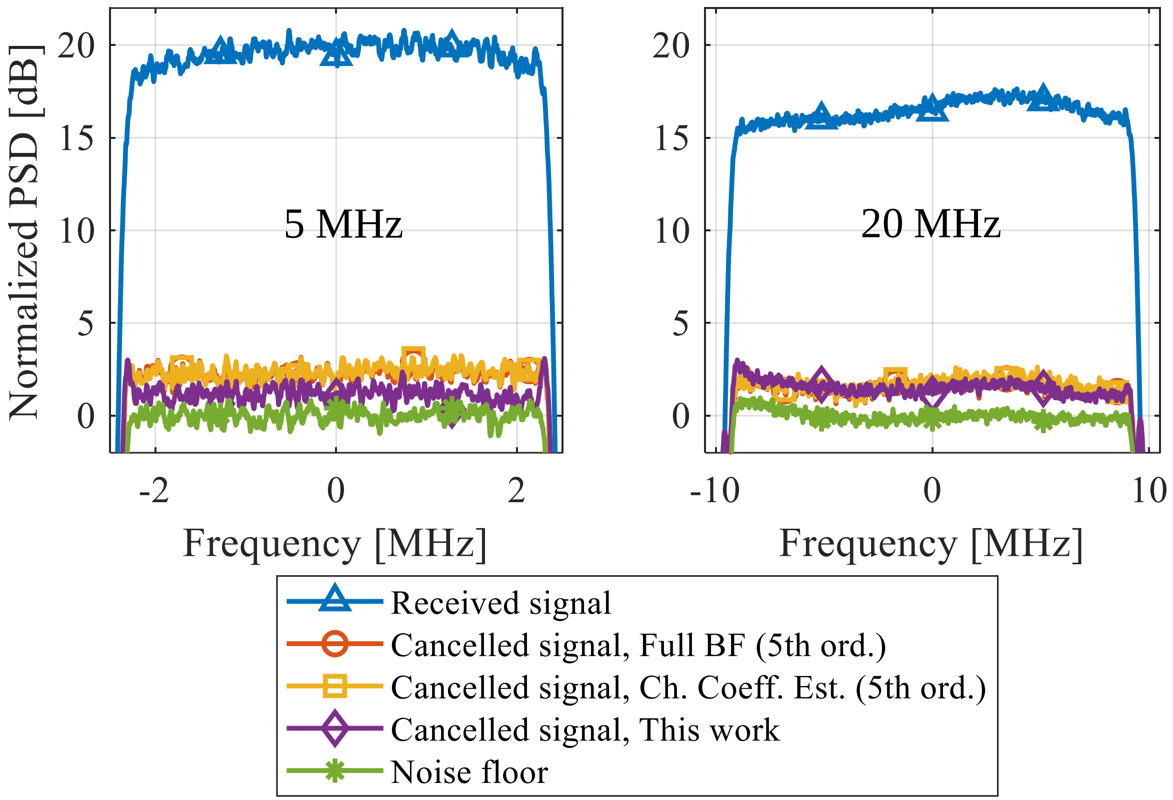
- Two cases with 5 MHz and 20 MHz carriers, comparing to previous models (Full BF; Ch. Coeff. Est.) [1]
- Complexities given below in floating point operations (FLOPs) per sample

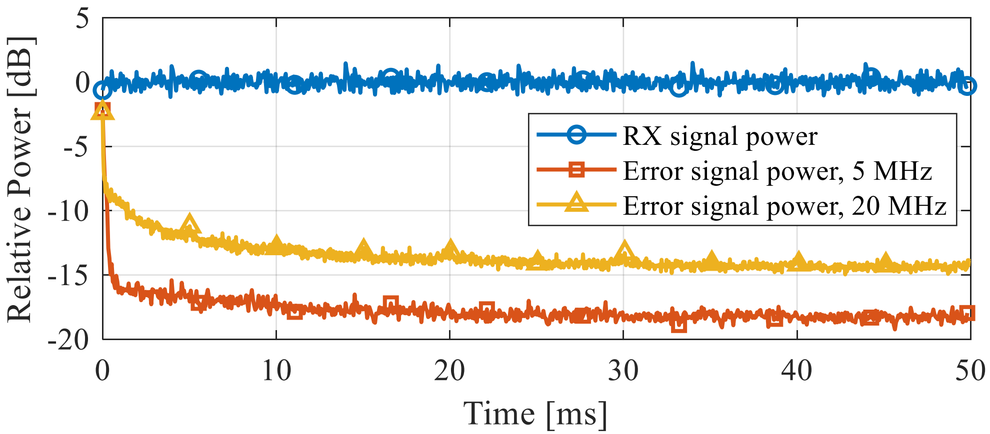
Model		This work	Full BF	Ch. Coeff. Est.
Main Path	5 MHz	196	4,554	404
	20 MHz	332		
Learning	5 MHz	6,280	1,843,200	10,142
	20 MHz	9,048		

[1] V. Lampu, L. Anttila, M. Turunen, M. Fleischer, J. Hellmann, and M. Valkama, "Air-Induced Passive Intermodulation in FDD MIMO Systems: Algorithms and Measurements," IEEE Trans. Microw. Theory Techn., vol. 71, no. 1, pp. 373–388, 2023.

4. Measurements & Results

- Performance of the reference models met or exceeded with cascade model
- Initial convergence in ~0.5 ms; full convergence in ~40 ms





5. Conclusion

- Air-induced PIM was discussed in a MIMO scenario
- Novel cascaded model to remove PIM from RX data
- Gradient descent-based updates for low complexity
- Performance on par with previous works but with lower complexity