

RFI filtering using Empirical Mode Decomposition

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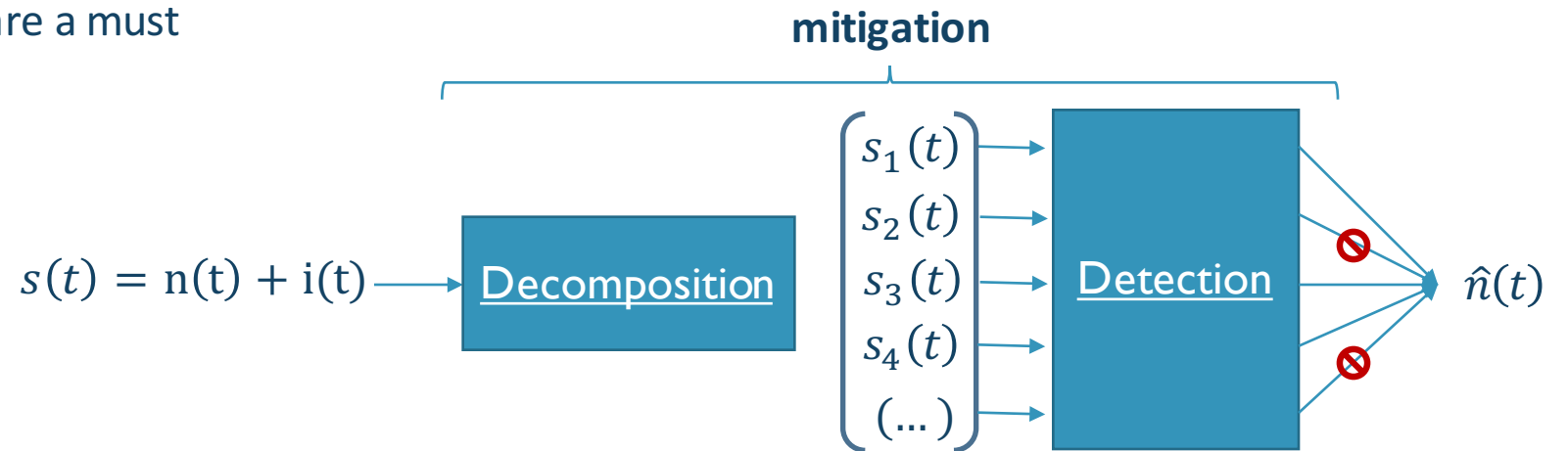
Introduction

Radio Frequency Interference (RFI): an increasing problem in Microwave Radiometry.

RFI contaminates data biasing measurements & preventing retrievals

Regulation enforcement is costly and often not enough.

On board mitigation systems are a must

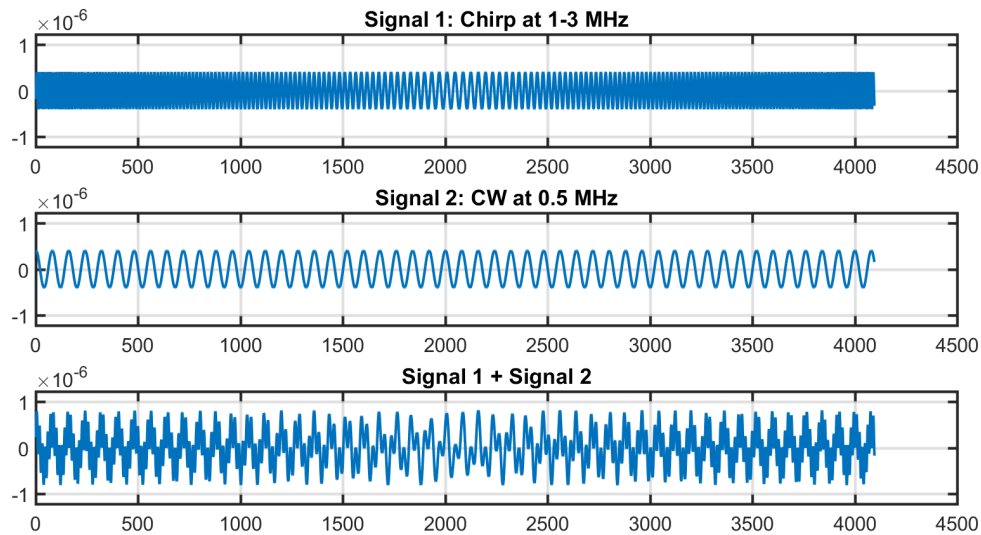


In this presentation,

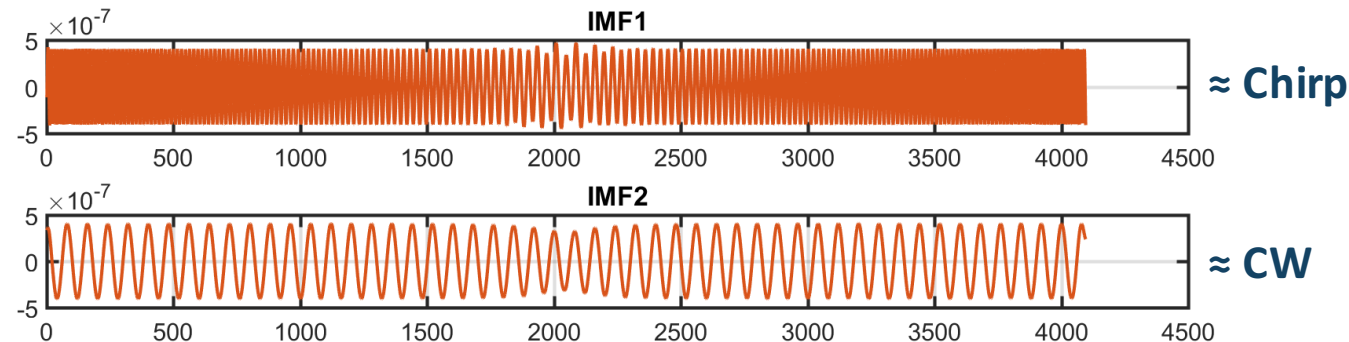
1. Empirical Mode Decomposition (EMD) is proposed as a decomposition tool
2. How RFI detection can be achieved
3. Mitigation performance studied

The Empirical Mode Decomposition: a non-linear signal processing tool

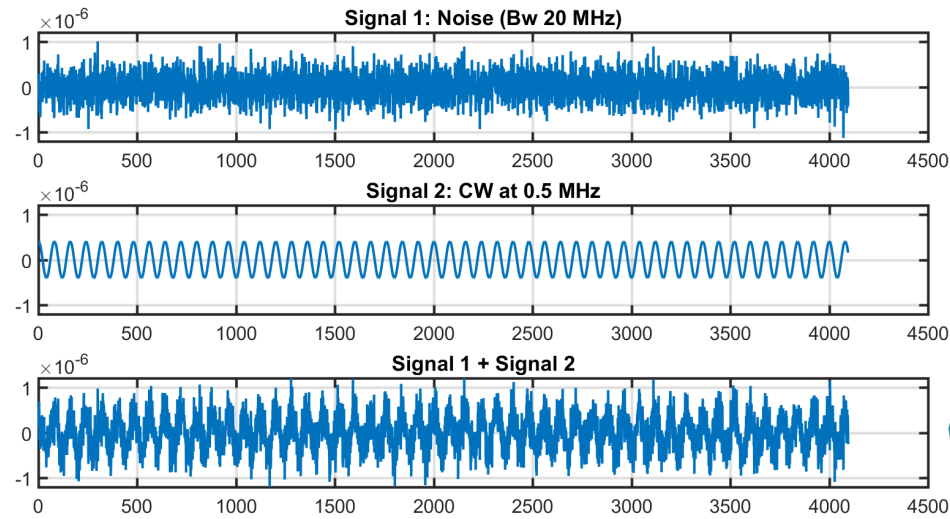
- EMD / Hilbert-Huang Transform (*Huang et. al. 1998*)
- EMD is a **non-linear iterative algorithm** able to decompose a signal in its constituent Intrinsic Mode Functions (“IMFs”)
- Each IMF \approx Sinusoid modulated in amplitude and frequency



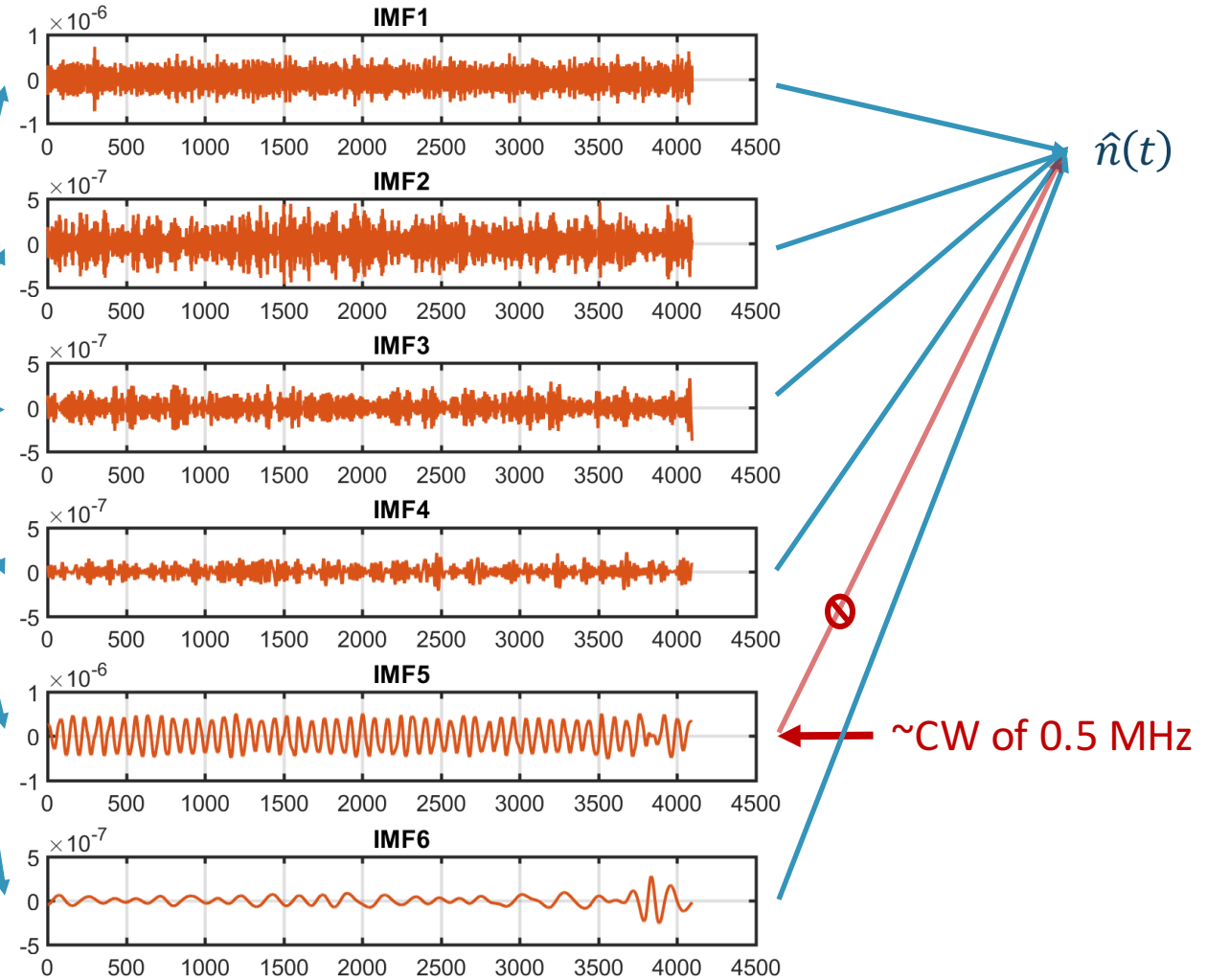
EMD



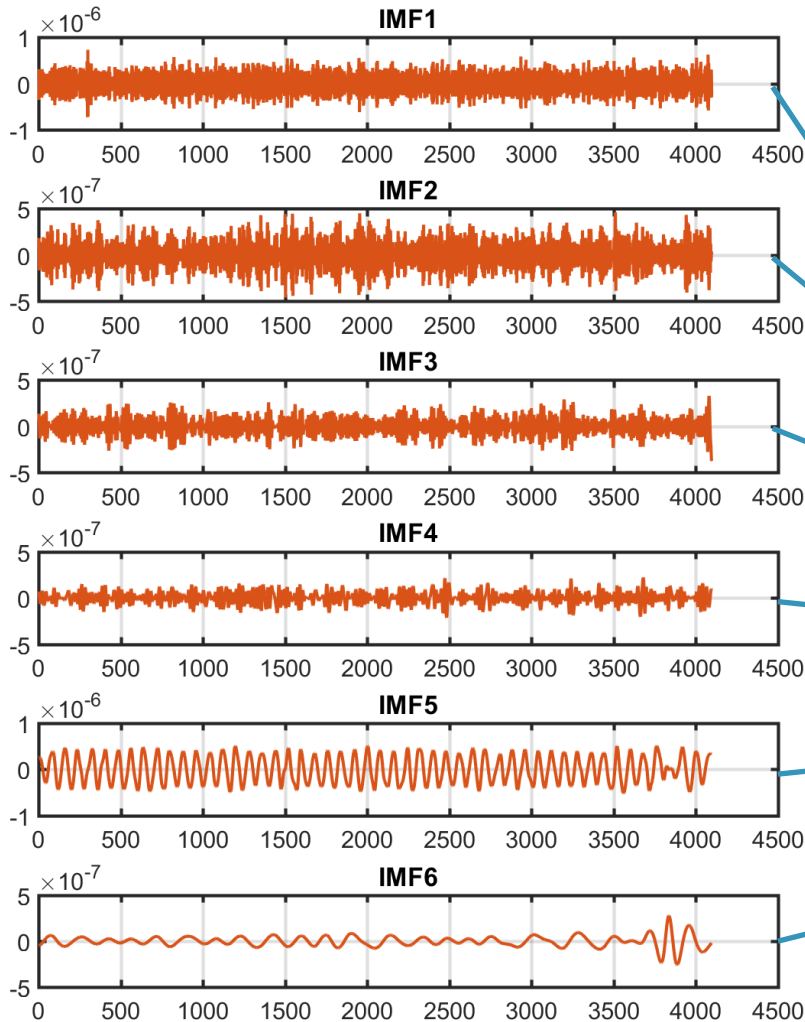
'Classical' EMD thresholding



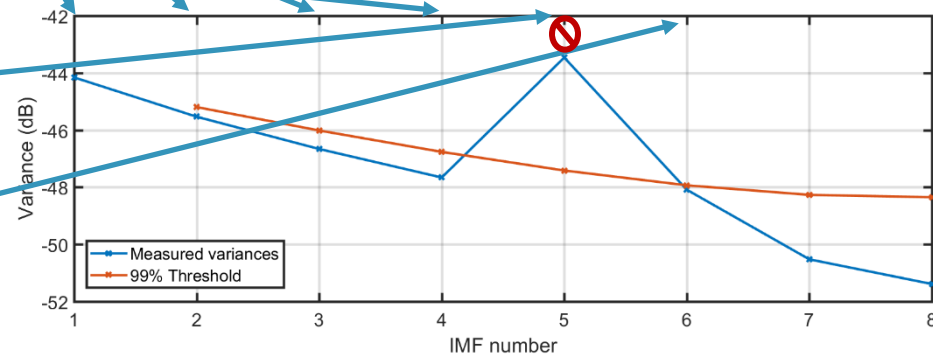
→ Originally proposed as a denoising algorithm



'Classical' EMD thresholding

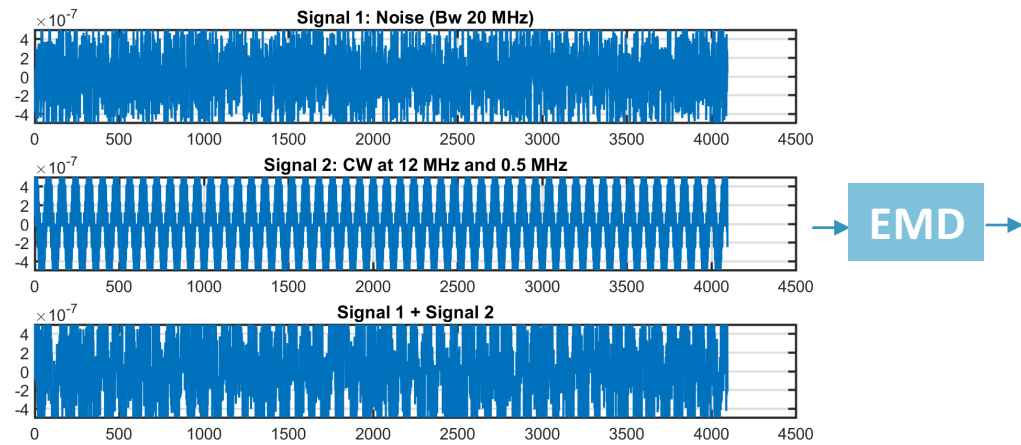


- No RFI: IMF variance decreases ~logarithmically from the first IMF
- This can be used to define a variance model & thresholds
- Any IMF variance > threshold is discarded
- Caveat: requires 1st IMF RFI-free
 - Only for low frequency signals



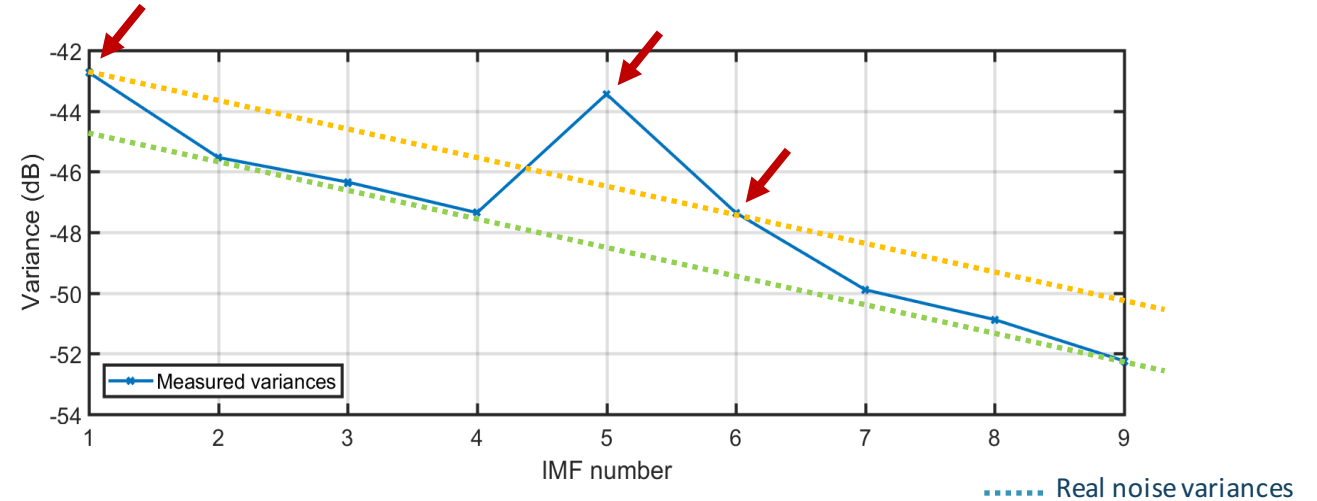
'Classical' EMD thresholding

- Classical EMD is of very limited use in RFI mitigation when RFI frequency is $f > Bw/4$



Example with high-frequency RFI

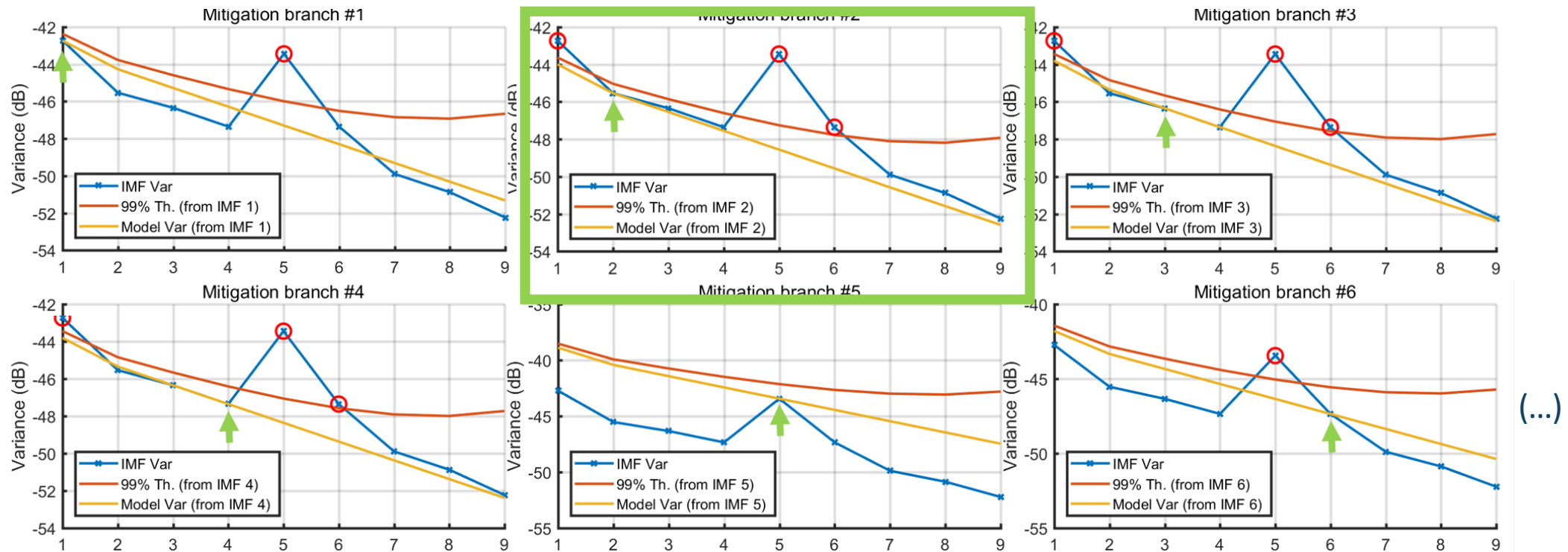
First IMF is contaminated by RFI, will not be detected by Classical EMD



A refinement is proposed: 'Multicomponent' EMD thresholding

'Multicomponent' EMD thresholding

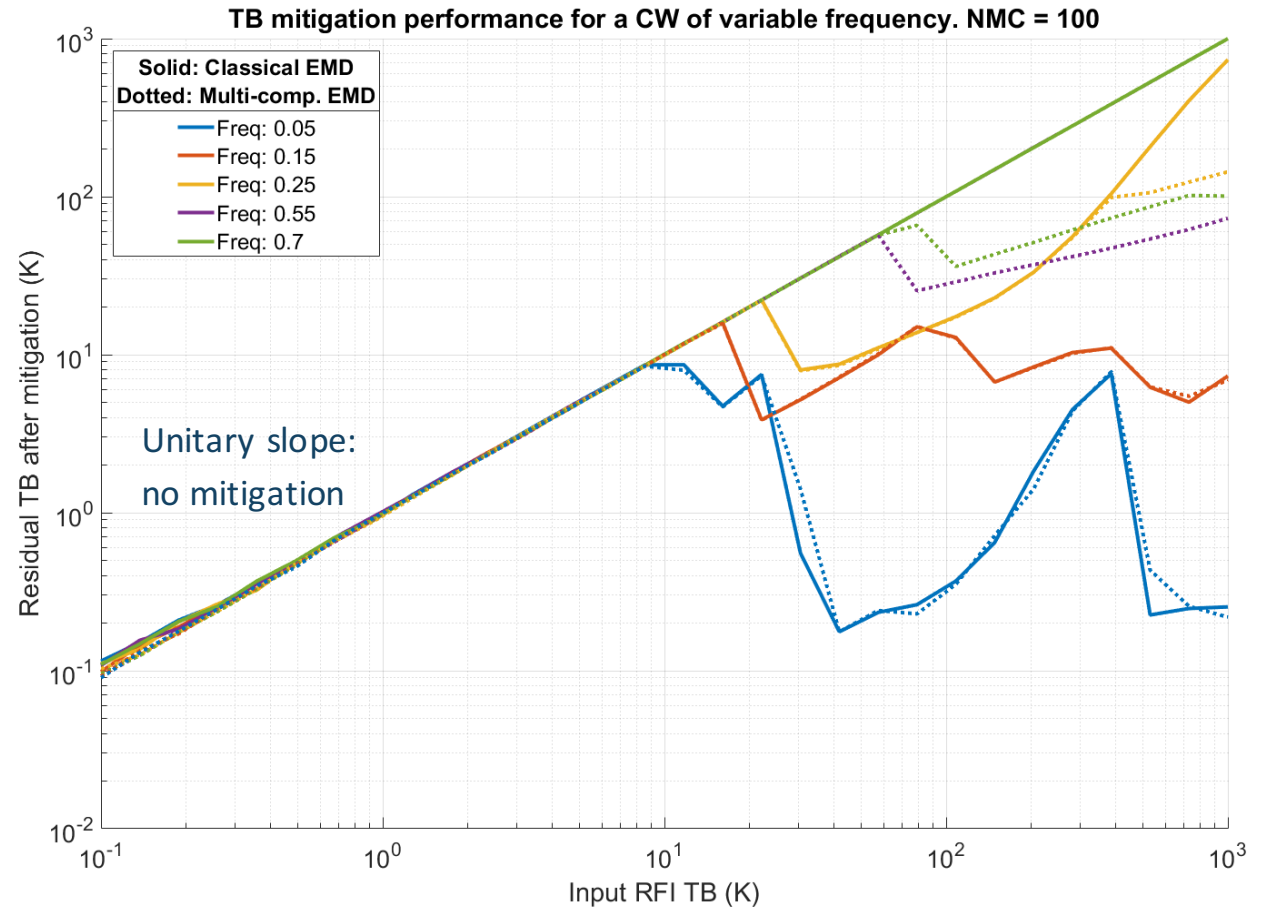
- Runs as many detection branches as IMFs available, each with a threshold tailored to it
- No need of assuming that the 1st IMF is clean
- Best mitigation is selected by keeping the lower power after mitigation (assuming proper compensation)



Classical EMD vs “Multicomponent” EMD

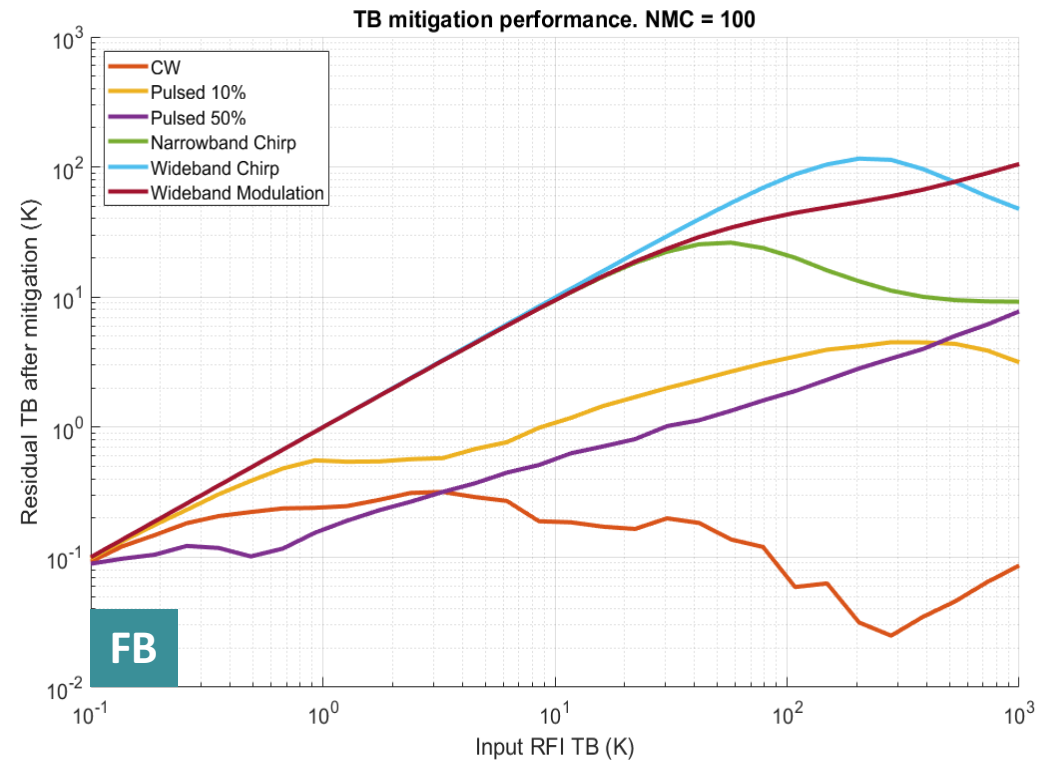
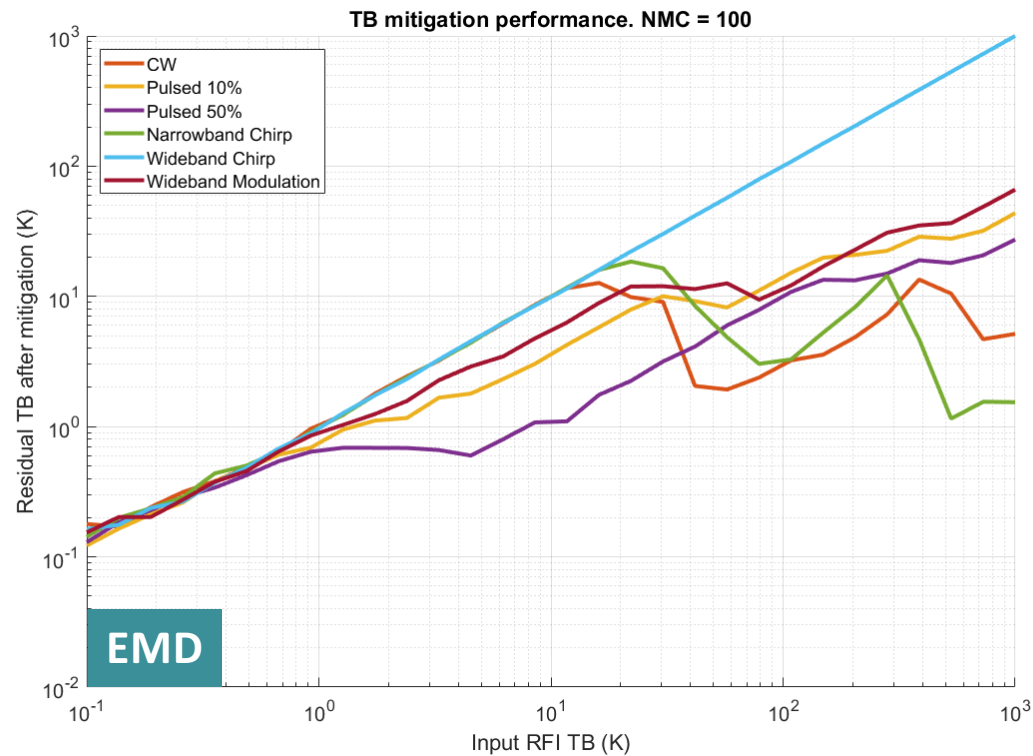
- Main performance metric: Residual RFI power after mitigation vs input RFI power
- For a CW of variable freq.

- Classical EMD not working for $f > Bw/4$
- Multi-component EMD thresholding working regardless of frequency
- High dependence of performance with frequency – EMD well tailored for low frequency signals, but not so much for high frequency



Performance assessment vs RFI type:

- Main performance metric: Residual RFI power after mitigation vs input RFI power
- Different RFI types



EMD is a capable method to mitigate most types of RFI (except wideband chirps)

EMD > FB in some specific cases (PRN modulations, narrowband chirps), but FB > EMD for other CW & Pulsed

Conclusions

- New non-linear decomposition algorithm tested for RFI mitigation in Microwave Radiometry
- Classical EMD thresholding limitations shown
- A refinement has been proposed to tailor it to RFI context: **“Multi-component” EMD thresholding**
- Performance has been studied and compared to FB
 - EMD well tailored for low-frequency RFI, not so much for high frequency RFI
 - EMD > FB for narrowband chirps & PRNs
 - FB > EMD for pulsed & CW
- Given the high complexity of EMD, it is not a generalist RFI mitigation method at this stage of research
- First step on assessing non-linear RFI decomposition methods

Thank you for your attention

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