EDISON

Electromagnetic Design of
flexIble SensOrs

FNP Team-Tech

Report 6 - CRBM Research

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Revision	Date	Author(s)	Description
1.0	22.08.2017		created

Fro norm is computed with:

Theorem 6.1 (Schmidt-Eckart-Young). *Given a matrix* $\mathbb{A} \in \mathbb{R}^{m\times n}$ *of rank* r, *the matrix*

$$\mathbb{A}_k = \sum_{i=1}^{k} \sigma_i \zeta_i \psi_i^T, \qquad 0 \le k \le r, \tag{6.4}$$

satisfies the optimality property

$$\|\mathbb{A} - \mathbb{A}_k\|_F = \min_{\substack{\mathbb{B}\in\mathbb{R}^{m\times n} \\ \text{rank}(\mathbb{B}) \le k}} \|\mathbb{A} - \mathbb{B}\|_F = \sqrt{\sum_{i=k+1}^{r} \sigma_i^2}. \tag{6.5}$$

Figure 1: Fro norm formula for green dashed line.

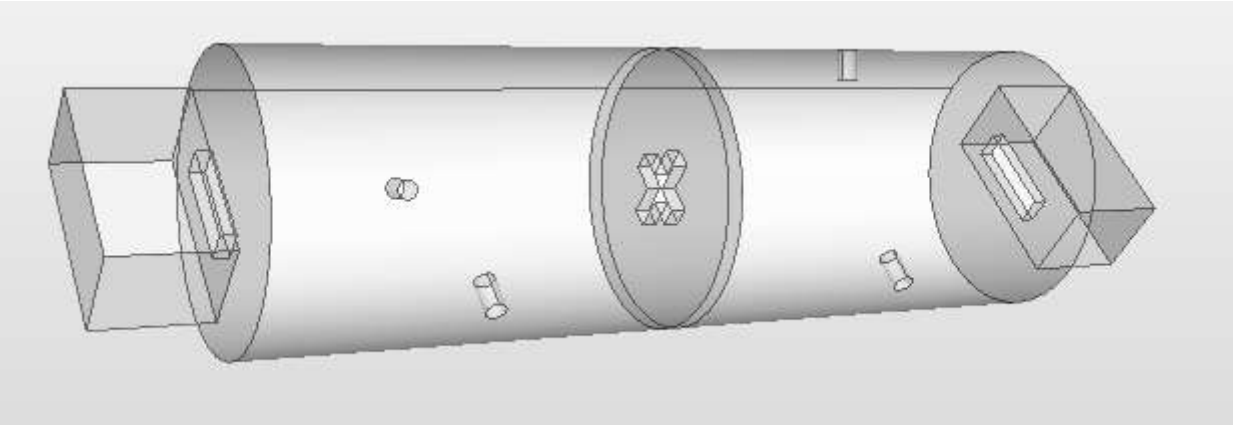


Figure 2: CFilter 30k and 100k DoF.

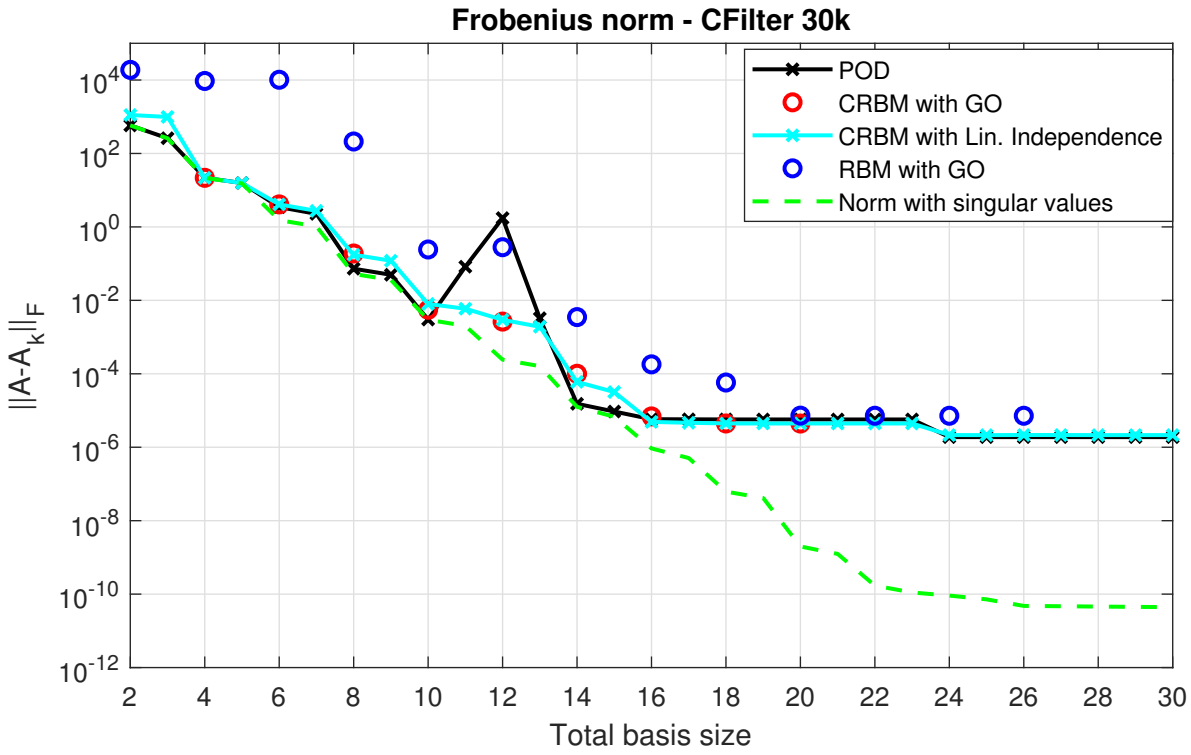


Figure 3: Frobenius norm.

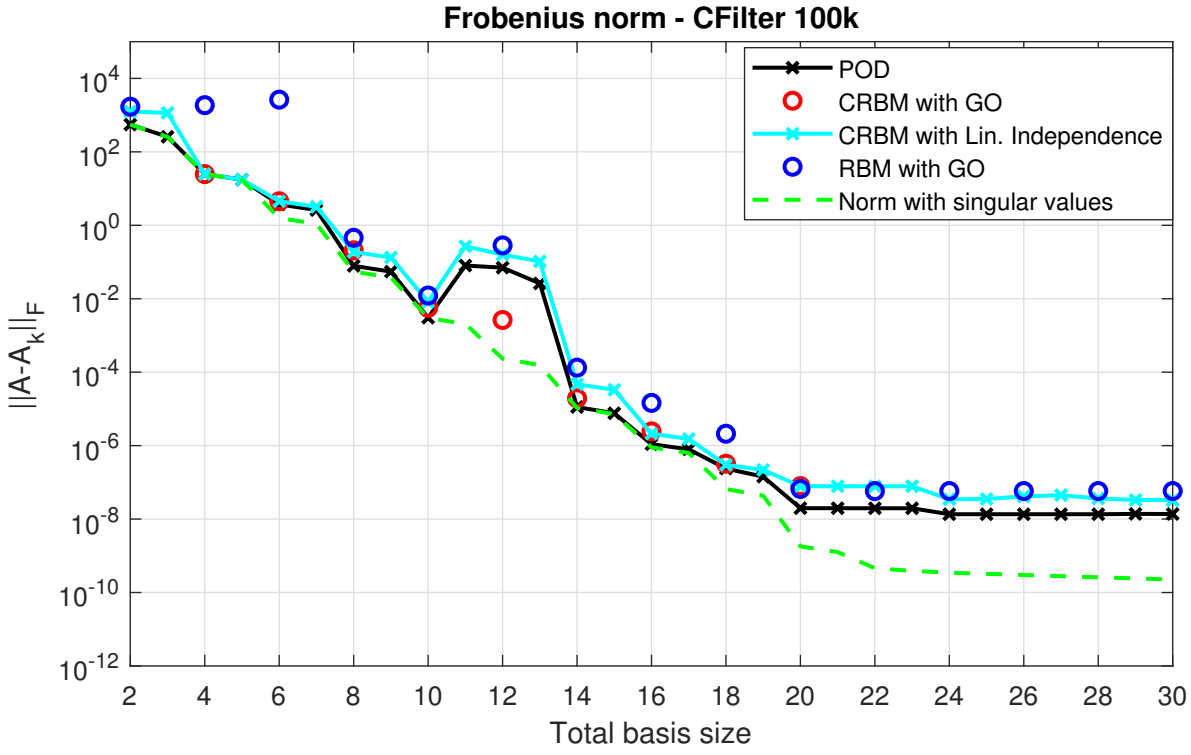


Figure 4: Frobenius norm.

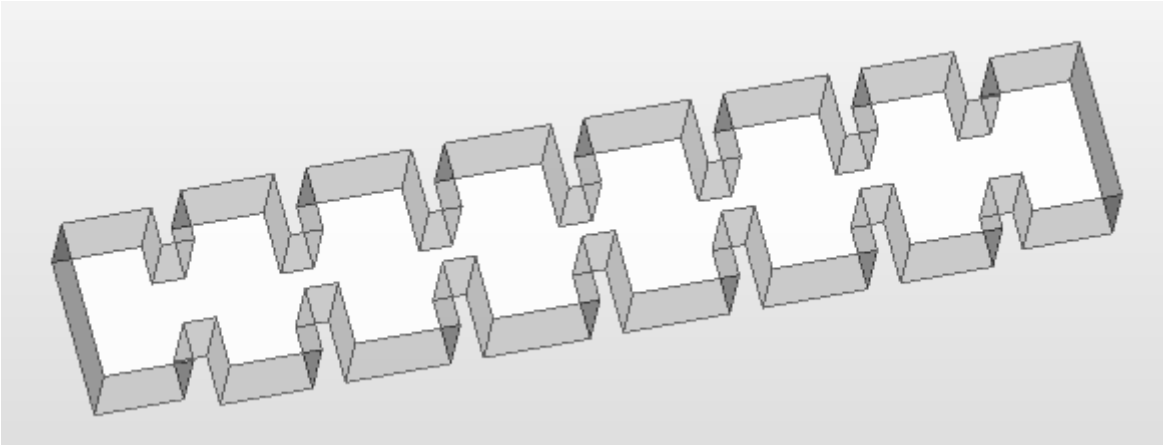


Figure 5: HPlane filter 43k DoF.

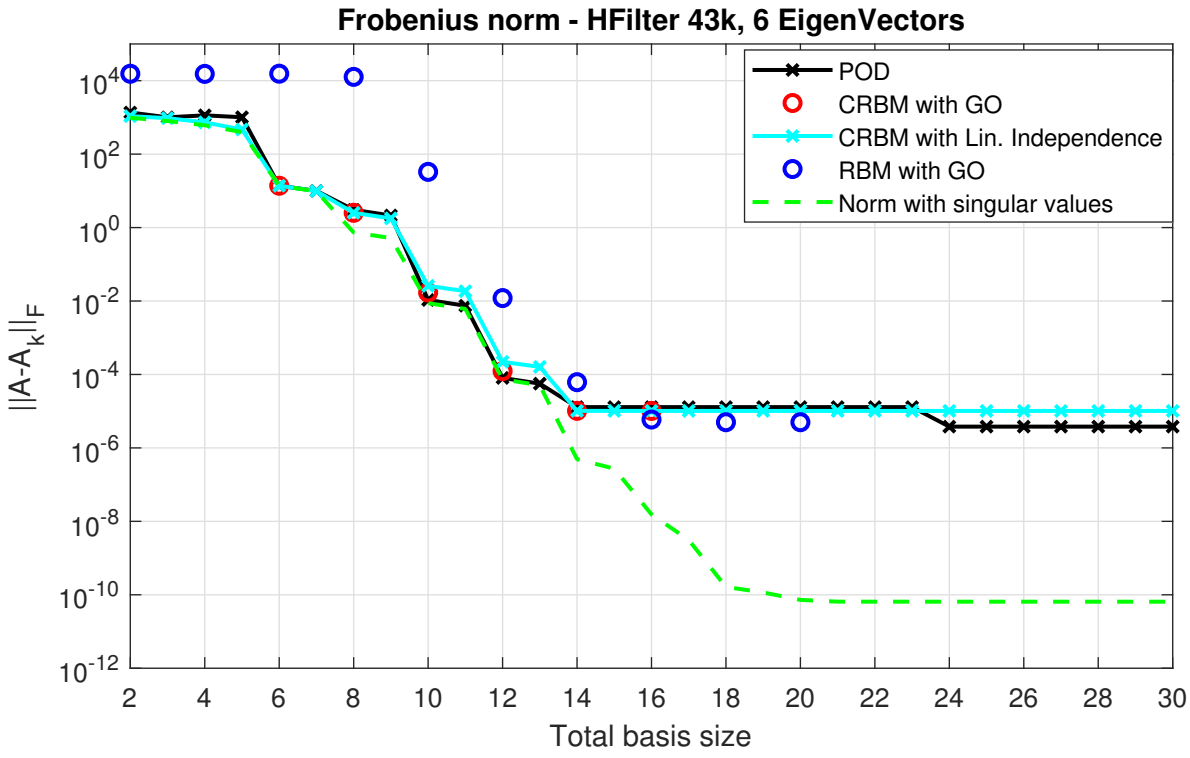


Figure 6: Frobenius norm.

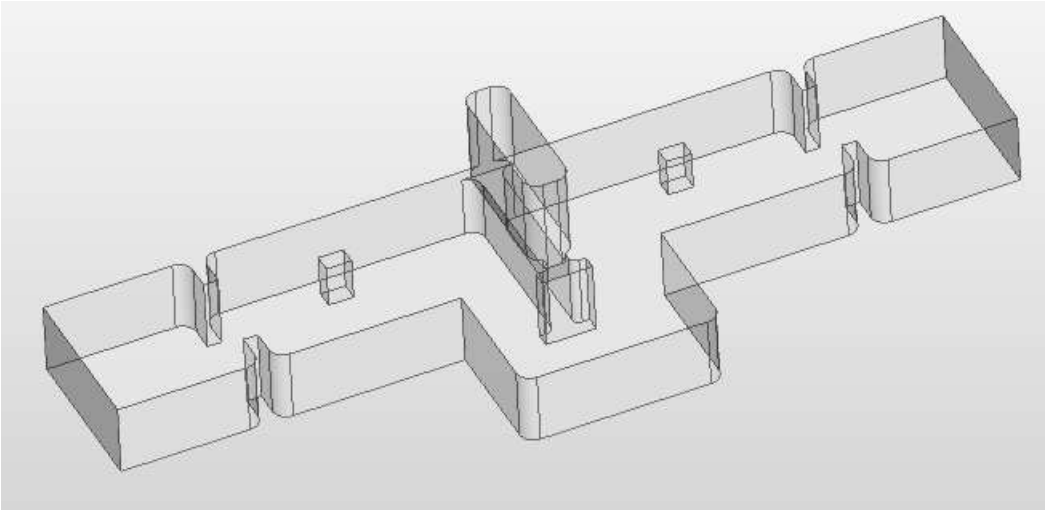


Figure 7: MFilter 100k DoF.

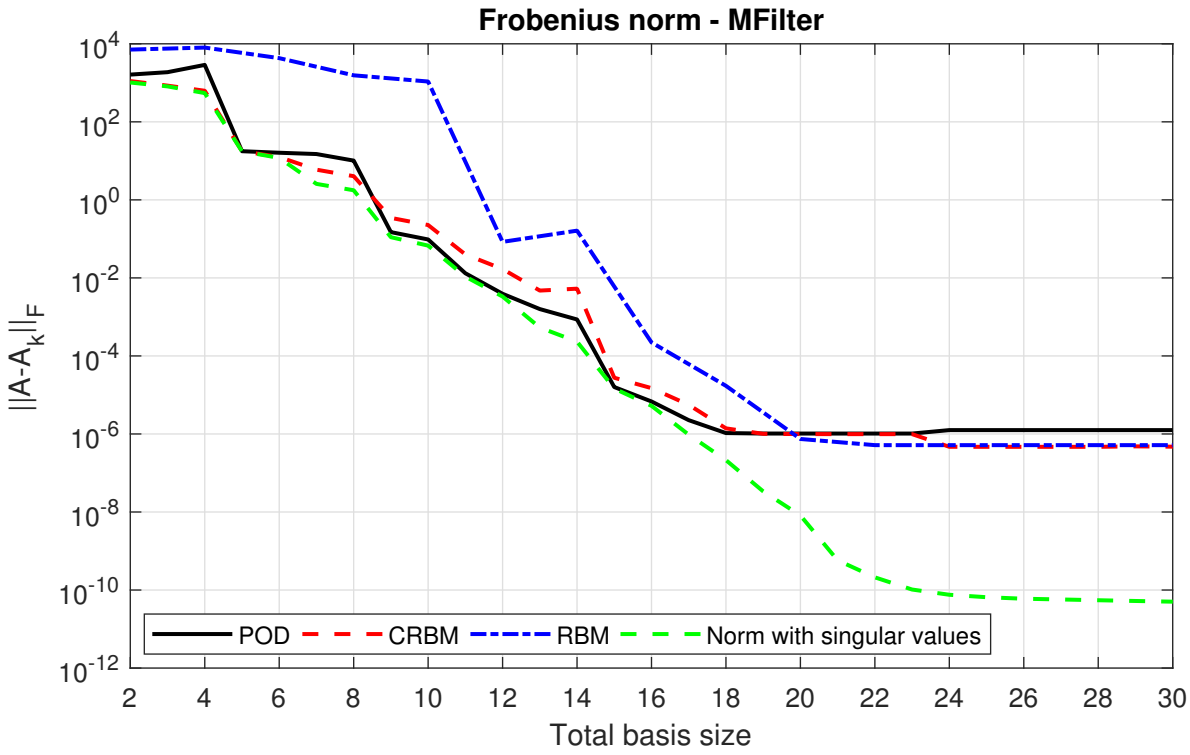


Figure 8: Frobenius norm.

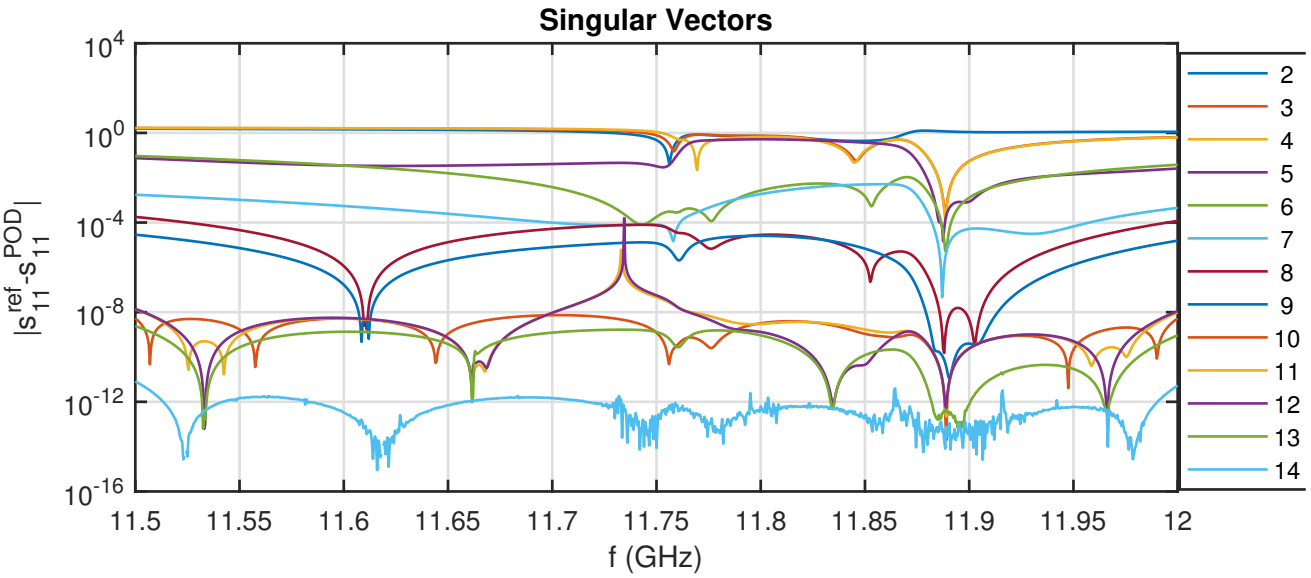


Figure 9: POD vectors, S parameters error.

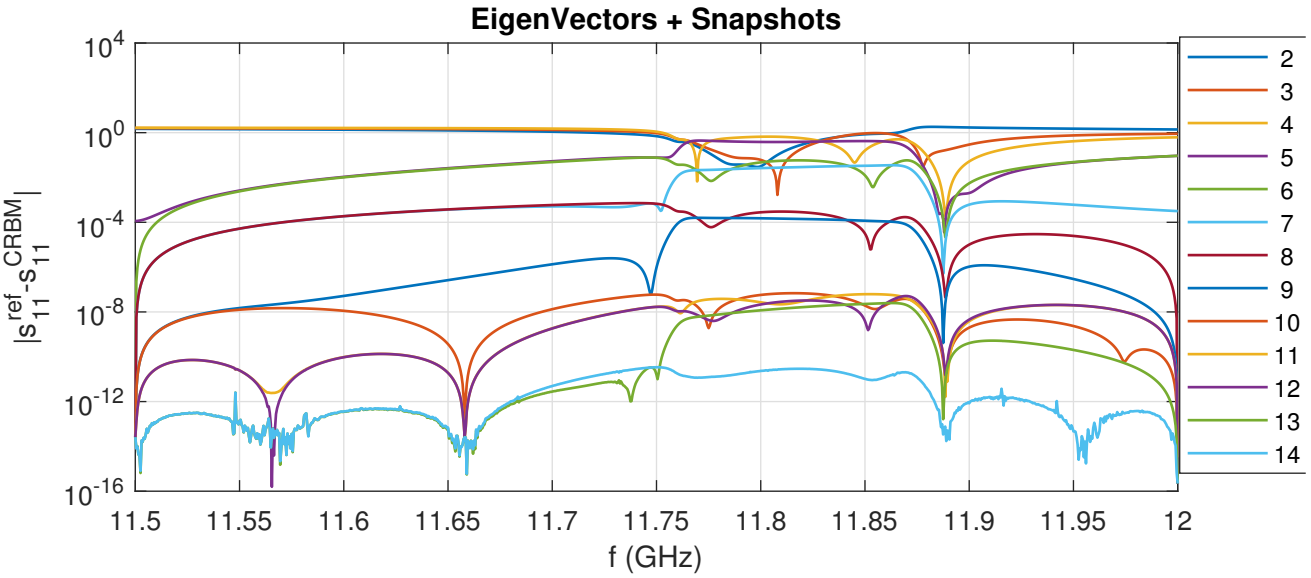


Figure 10: CRBM vectors, S parameters error. Vectors f=[11.5000 12.0000 11.6580 11.5660 11.9555] GHz. Selection is based on linear independence of vectors.

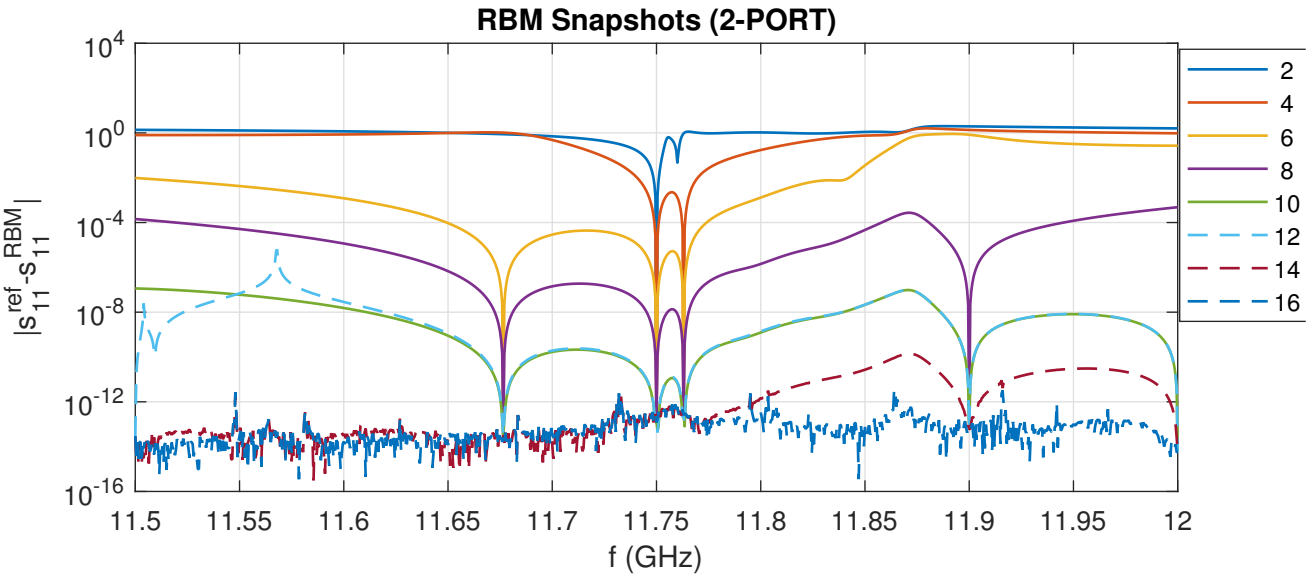


Figure 11: Legend contains total size of current basis - RBM vectors using S-oriented error estimator starting with 11.75 GHz snapshot.

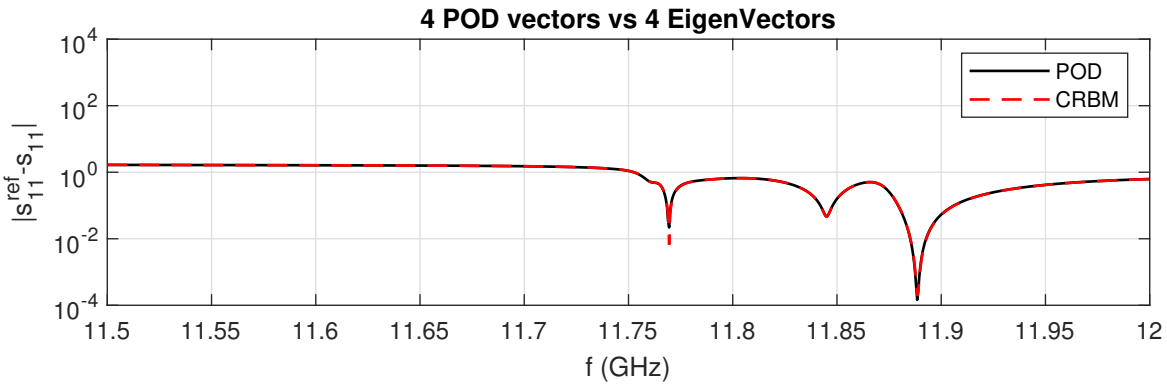


Figure 12: S param error using ROM constructed with 4 EV XOR 4 POD vectors (orange plot at Fig.10 and Fig.9).

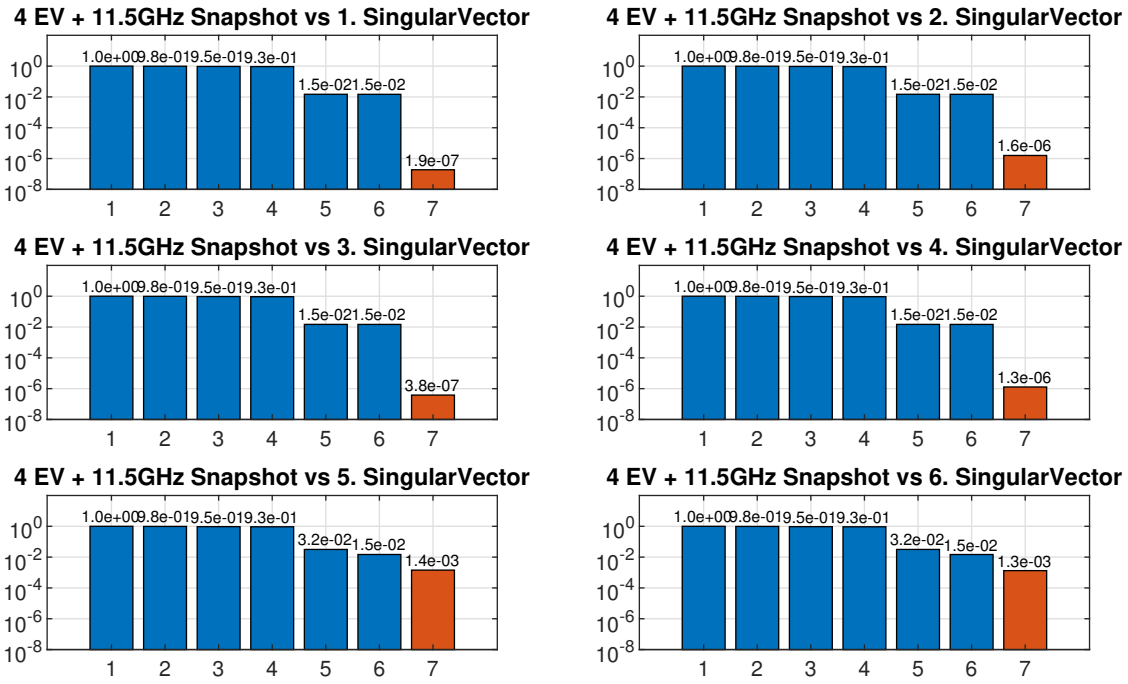


Figure 13: Singular values of set (4 EV + 1 Snapshot (2 port) and 1 SV).

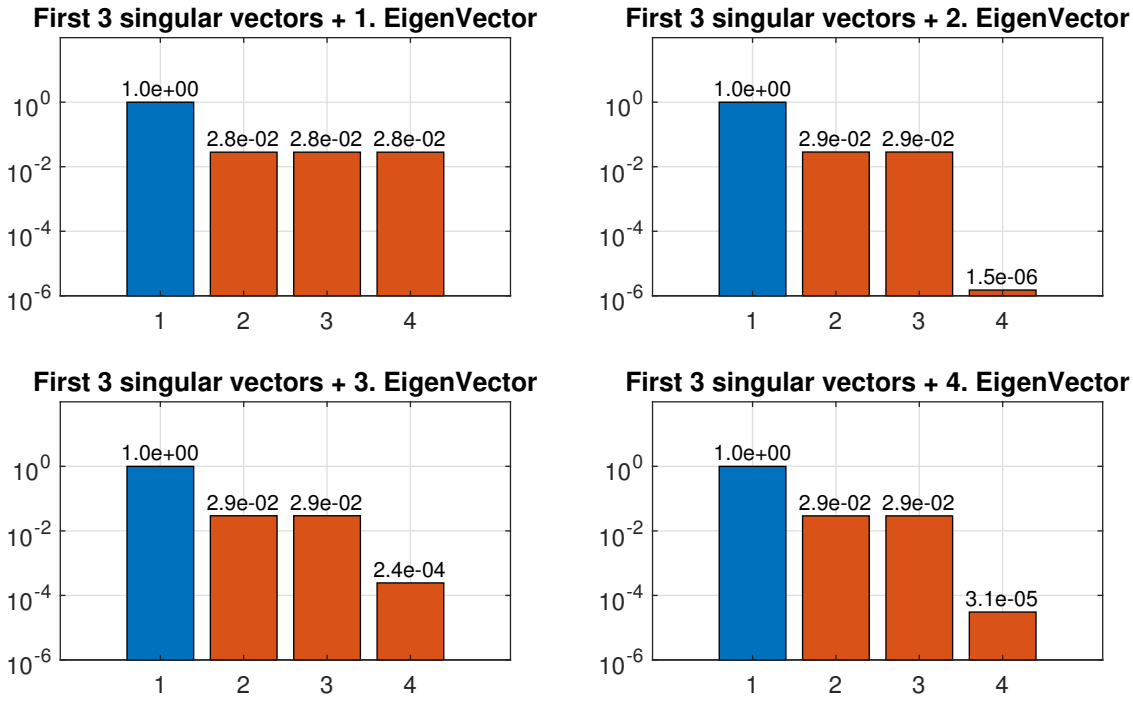


Figure 14: Singular values of set (3 SV and 1 EV).

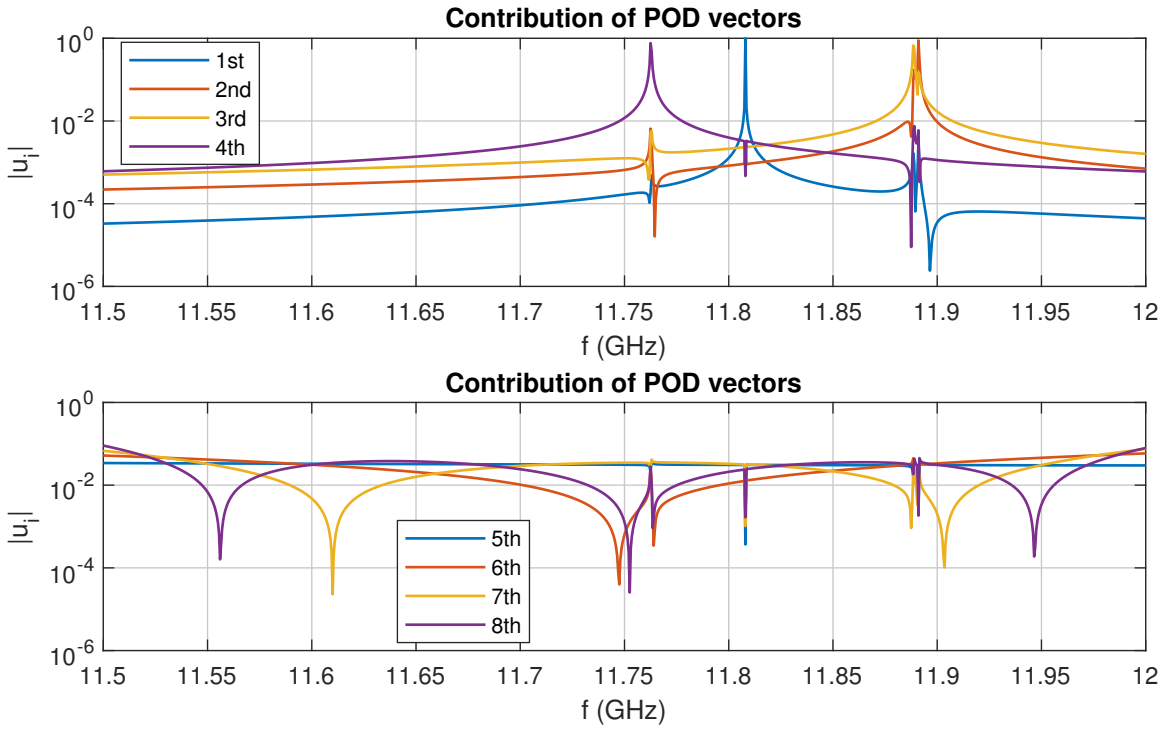


Figure 15: Contribution in solution of POD vectors.

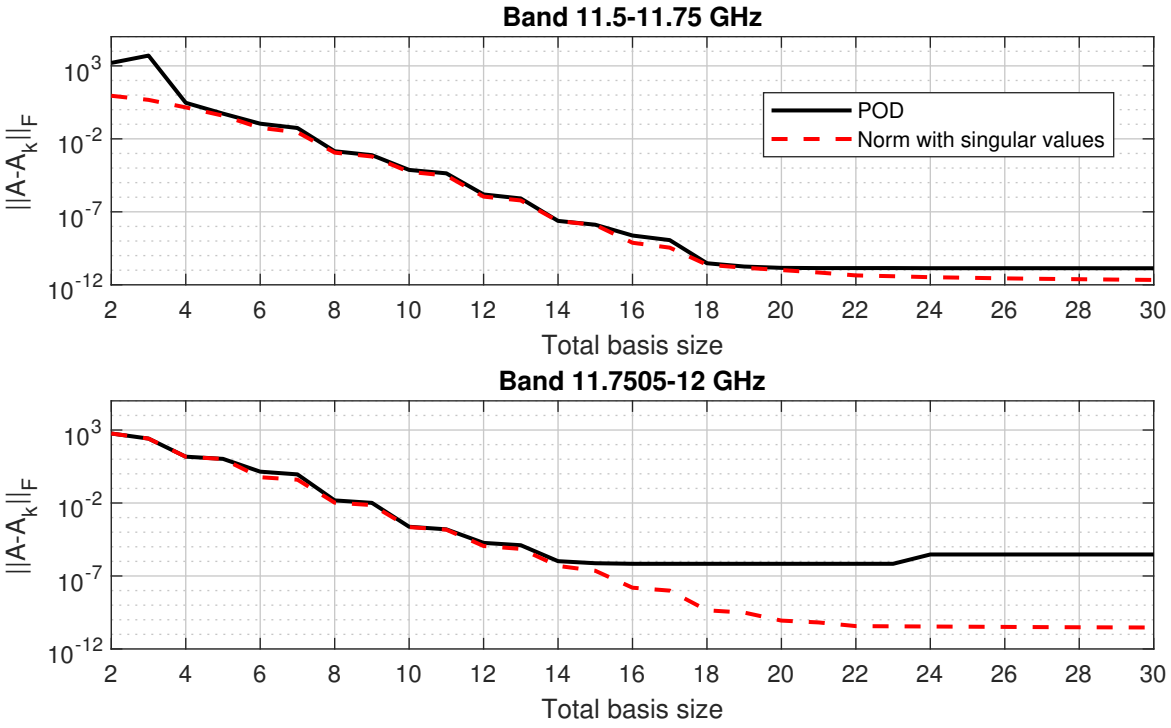


Figure 16: Fro norm in divided band.

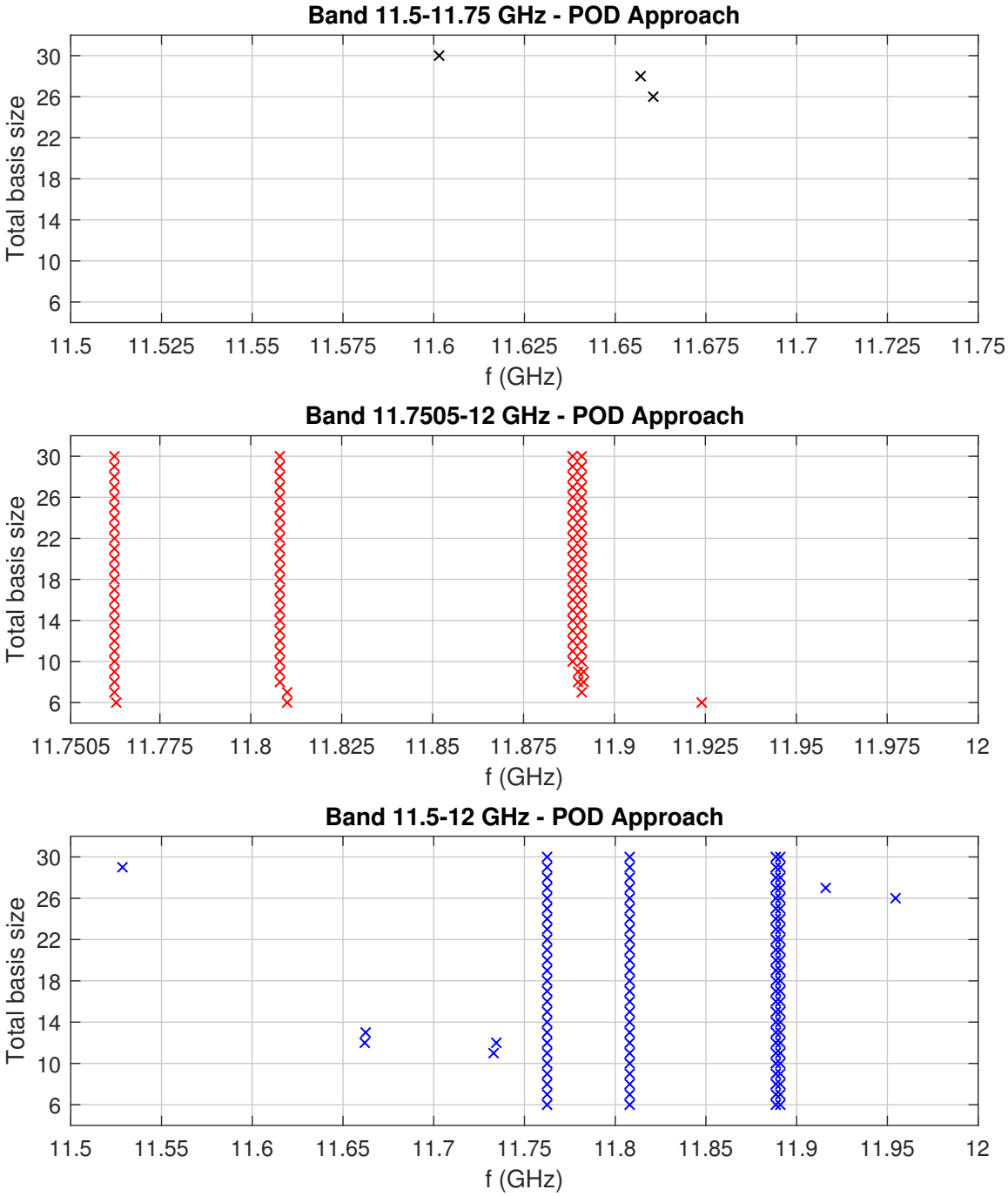


Figure 17: Eigenfrequencies. Poles in Madrid - POD case.

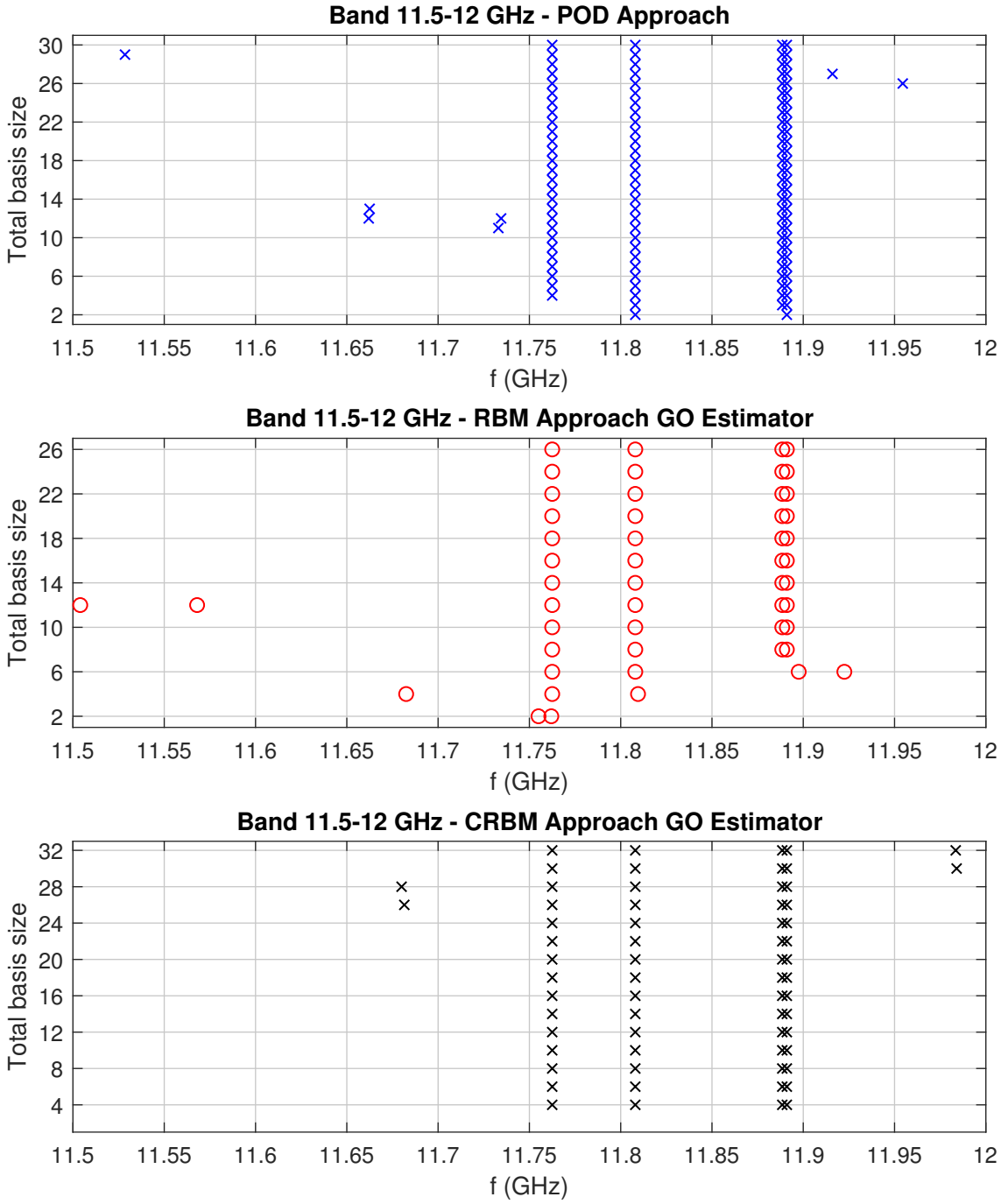


Figure 18: All eigenfrequencies in band.

New approach - looking for zeros in addition to poles

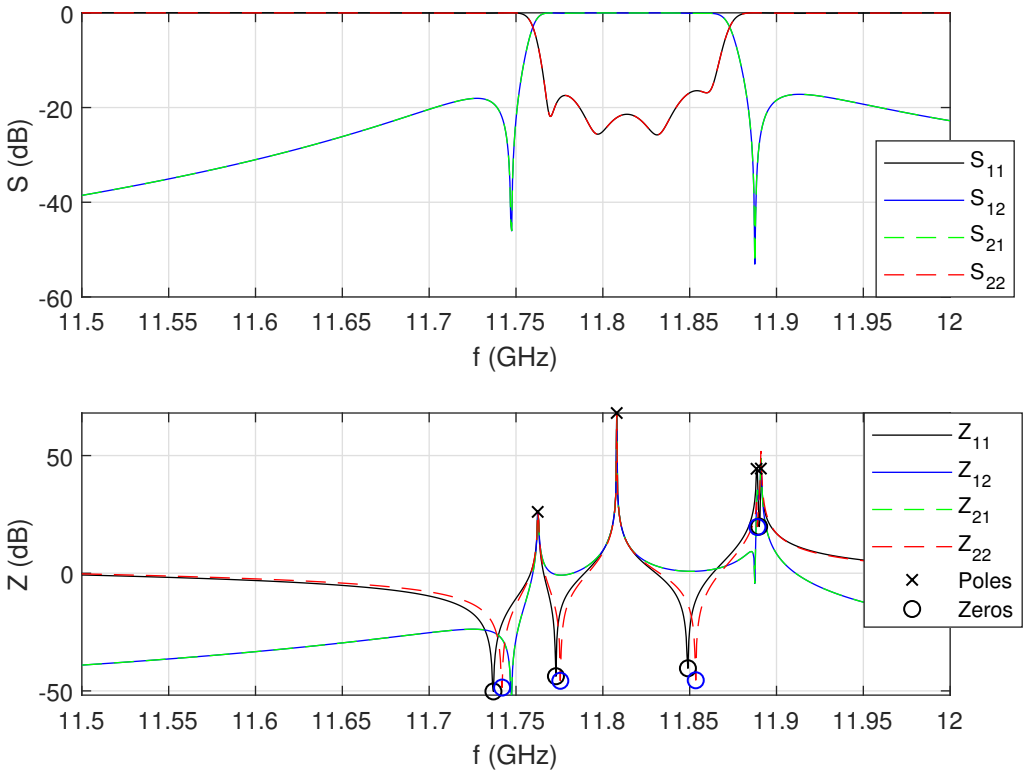


Figure 19: Zeros and poles of CFilter: Fig.2. The zeros around 11.88 GHz have high value cause of resolution. In total, there are 4 poles and 8 zeros in the analysed band. In addition, there are 2 snapshots present in the base: 11.5 and 12 GHz.

1. Basis is constructed as follows (Poles first **PoleZero=PZ**):

$$Basis = \begin{bmatrix} Poles(1:4) & Zero^{11}(1) & Zero^{22}(1) & Zero^{11}(2) & Zero^{22}(2) & \dots \end{bmatrix}$$

After all zeros and poles in the band are included it goes like this:

$$Basis = \begin{bmatrix} Basis & x(f = 11.5GHz) & x(f = 12GHz) \end{bmatrix}$$

After that we use most linear independent snapshots.

2. Basis is constructed as follows (Zeros first **ZeroPole=ZP**):

$$Basis = \begin{bmatrix} Zero^{11}(1) & Zero^{22}(1) & Zero^{11}(2) & Zero^{22}(2) & \dots & Poles(1:4) \end{bmatrix}$$

After all zeros and poles in the band are included it goes like this:

$$Basis = \begin{bmatrix} Basis & x(f = 11.5GHz) & x(f = 12GHz) \end{bmatrix}$$

After that we use most linear independent snapshots.

Zeros Z_{11}	Zeros Z_{22}	Poles
11.73678967	11.74180401	11.76269609
11.77289854	11.77559520	11.80801025
11.84882177	11.85339725	11.88873576
11.89022921	11.88889532	11.89112594
10.82711055	10.82759265	10.82759290
10.82392054	10.82346561	10.82392253
10.77368138	10.77368152	10.77368175
10.76973141	10.76972862	10.76973142
10.70324749	10.70324746	10.70324750
10.70006385	10.70006330	10.70006385
12.46085441	12.46085346	12.46085534
12.46329513	12.46329096	12.46329583

Table 2: Blue ones are in band. Red ones are on the left and black ones are on the right.

Value 1e-9 means that eigen frequency difference equals to 1 Hz.

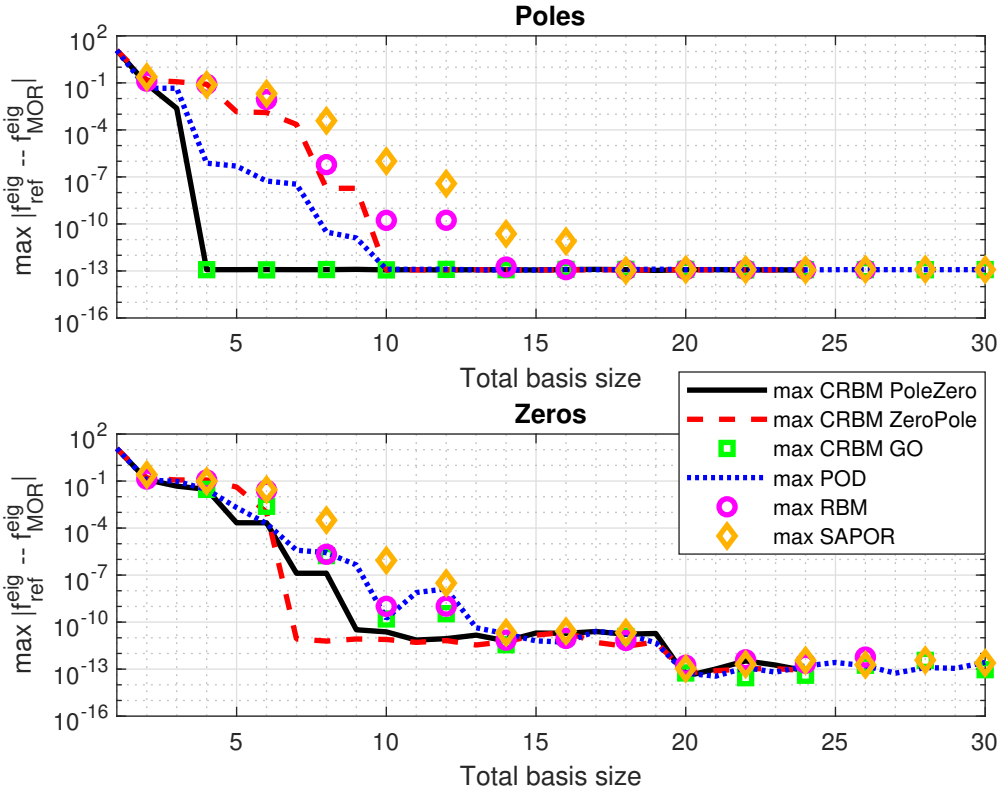
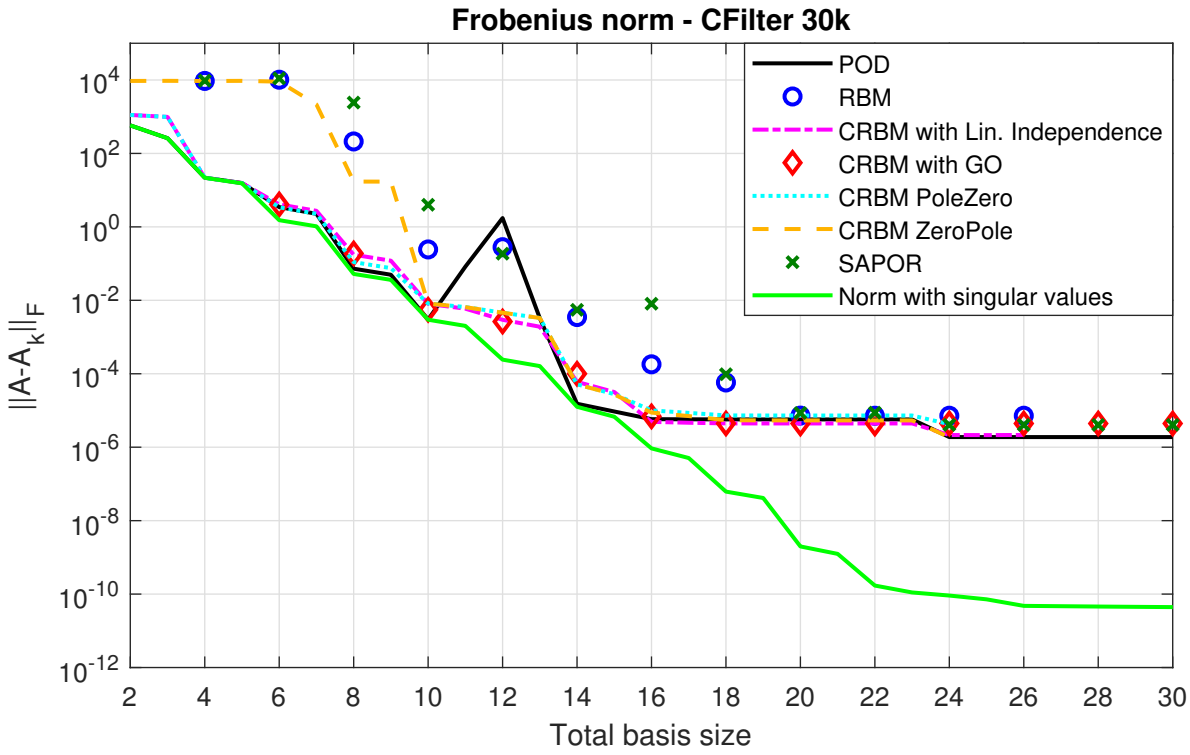
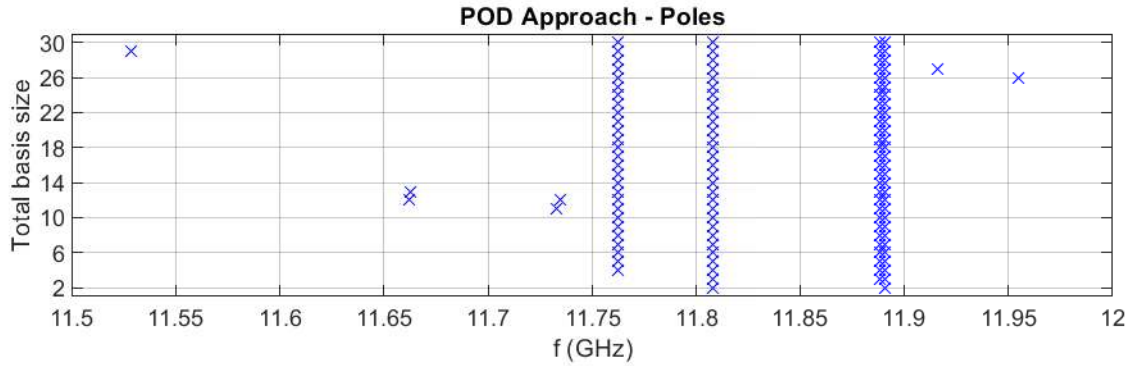
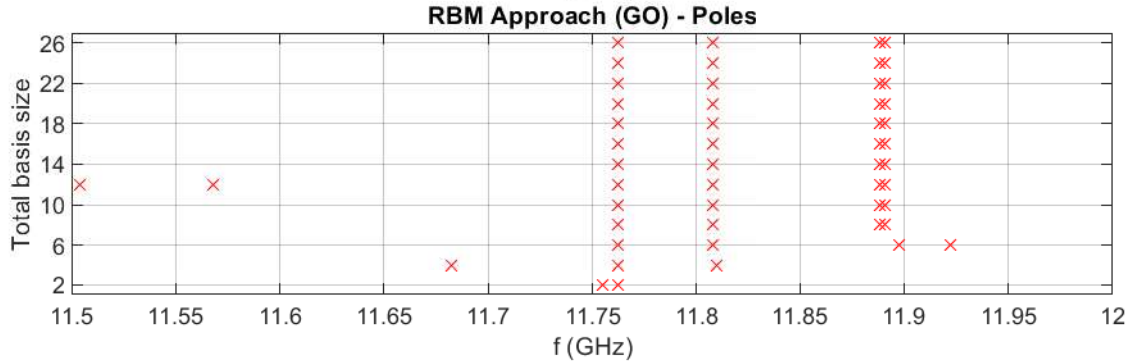
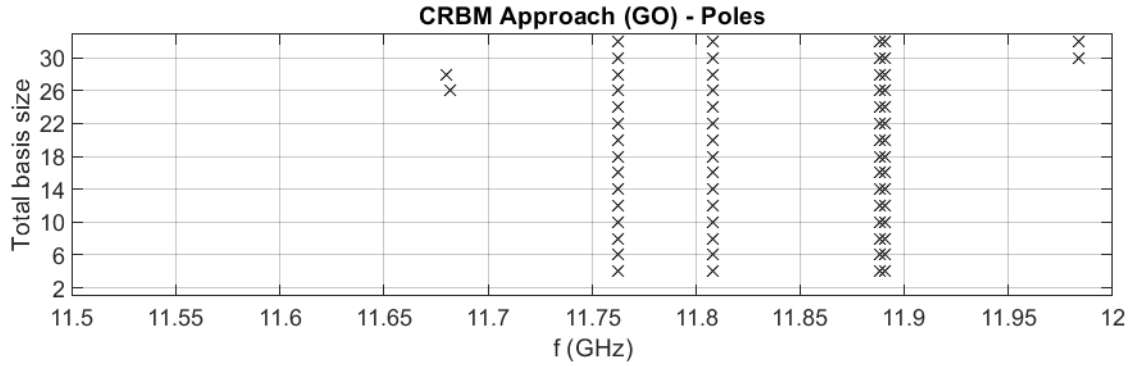


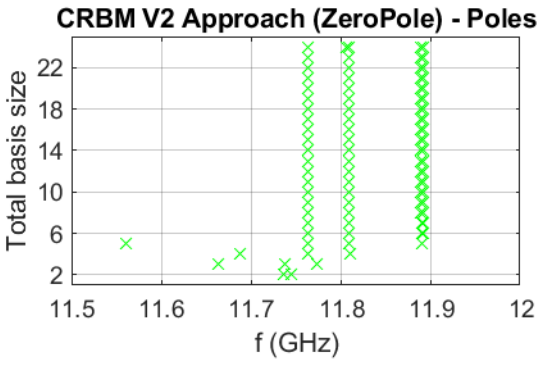
Figure 20: Maximum value of frequency difference example: |11.76-11.765|=0.005.

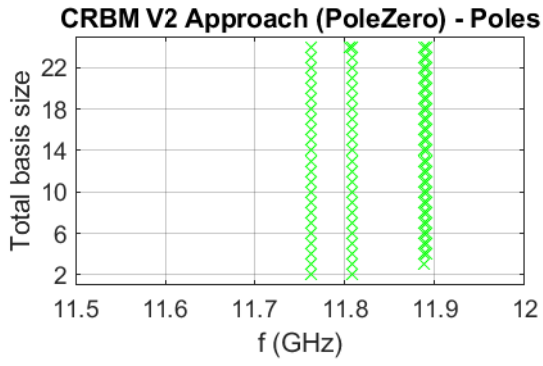

Frobenius norm - CFilter 30k
POD
RBM
CRBM with Lin. Independence
CRBM with GO
CRBM PoleZero
CRBM ZeroPole
SAPOR
Norm with singular values
$||A-A_k||_F$
10^{4}
10^{2}
10^{0}
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^{-12}
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
Total basis size

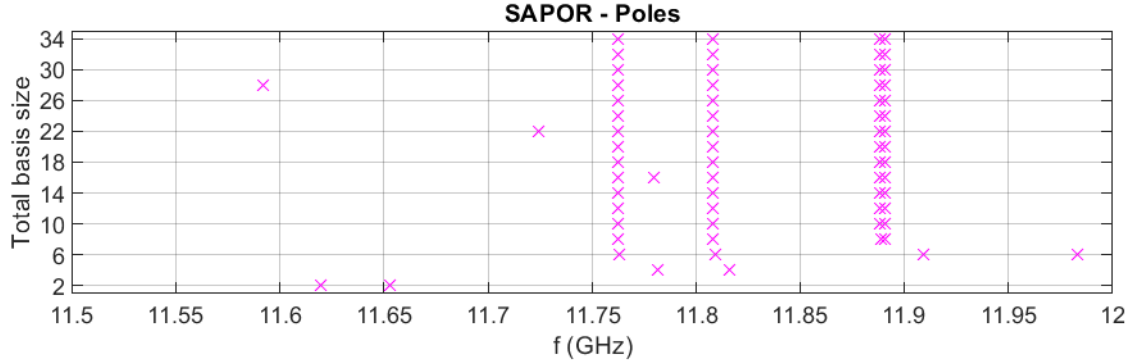

POD Approach - Poles
Total basis size
f (GHz)

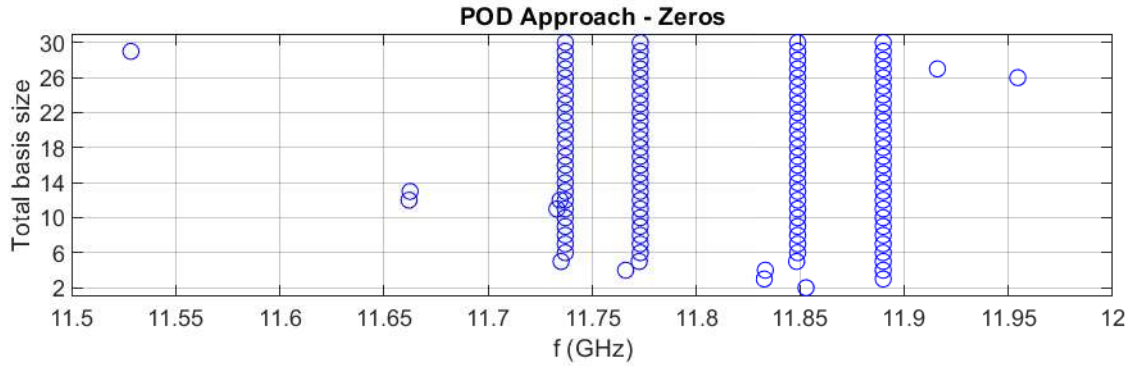

RBM Approach (GO) - Poles
Total basis size
f (GHz)

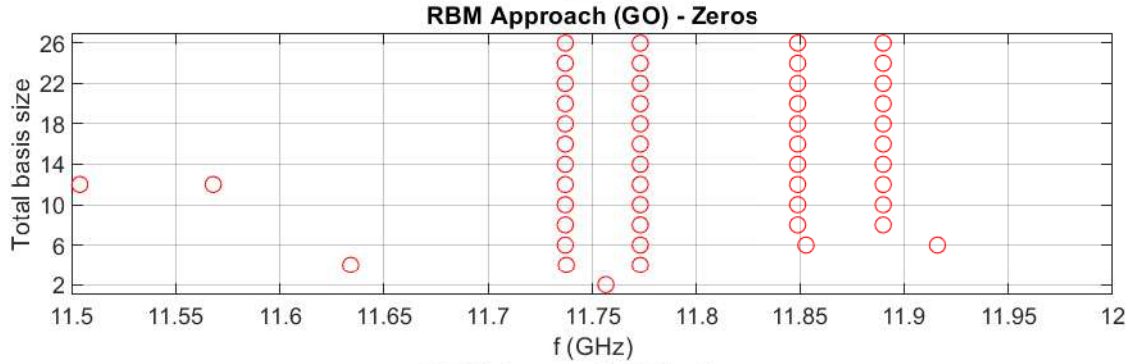

CRBM Approach (GO) - Poles
Total basis size
f (GHz)

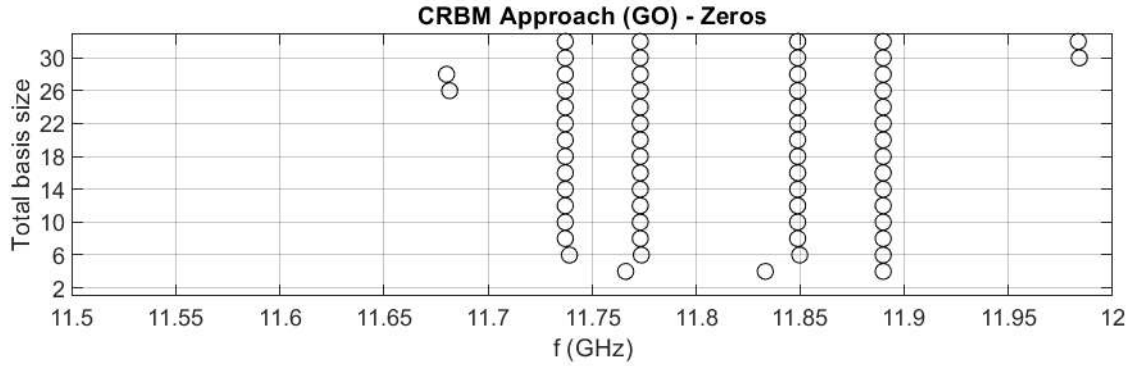

CRBM V2 Approach (ZeroPole) - Poles
Total basis size
f (GHz)

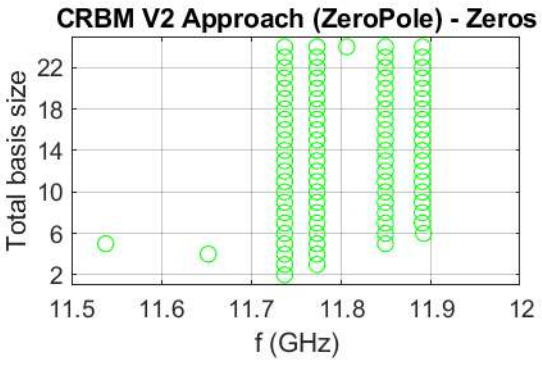

CRBM V2 Approach (PoleZero) - Poles
Total basis size
f (GHz)

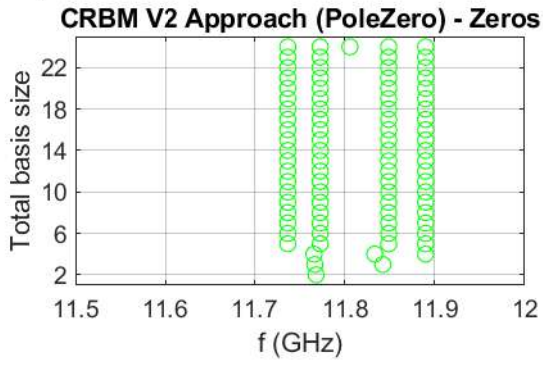

SAPOR - Poles
Total basis size
f (GHz)

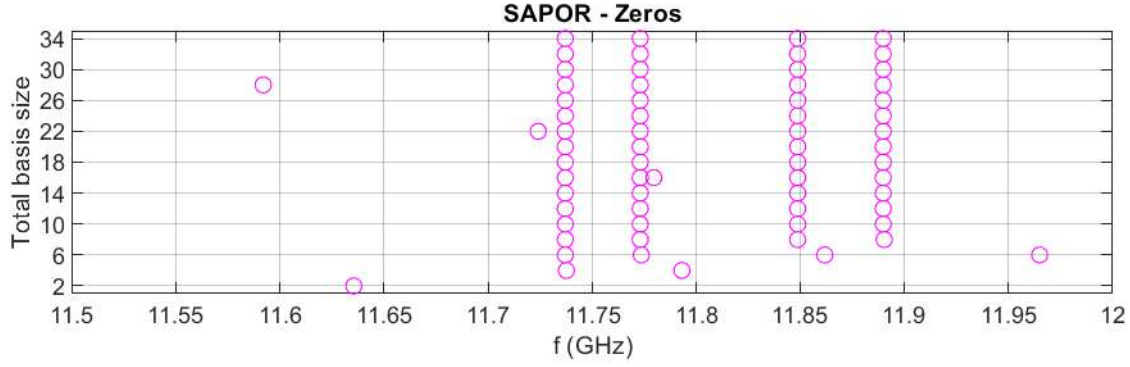

POD Approach - Zeros
Total basis size
f (GHz)


RBM Approach (GO) - Zeros
Total basis size
f (GHz)

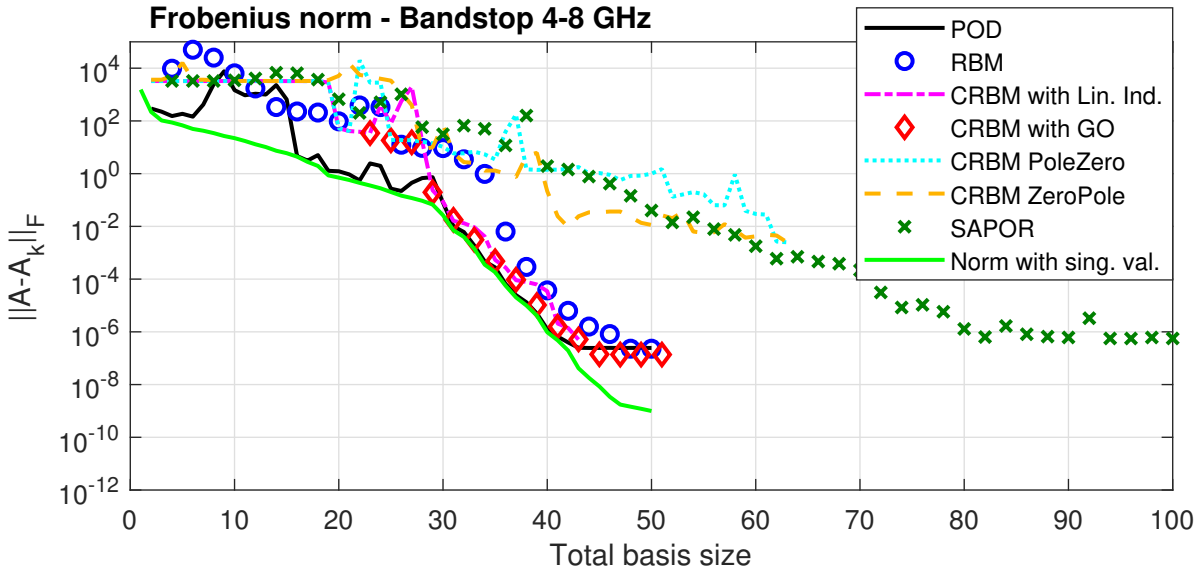

CRBM Approach (GO) - Zeros
Total basis size
f (GHz)

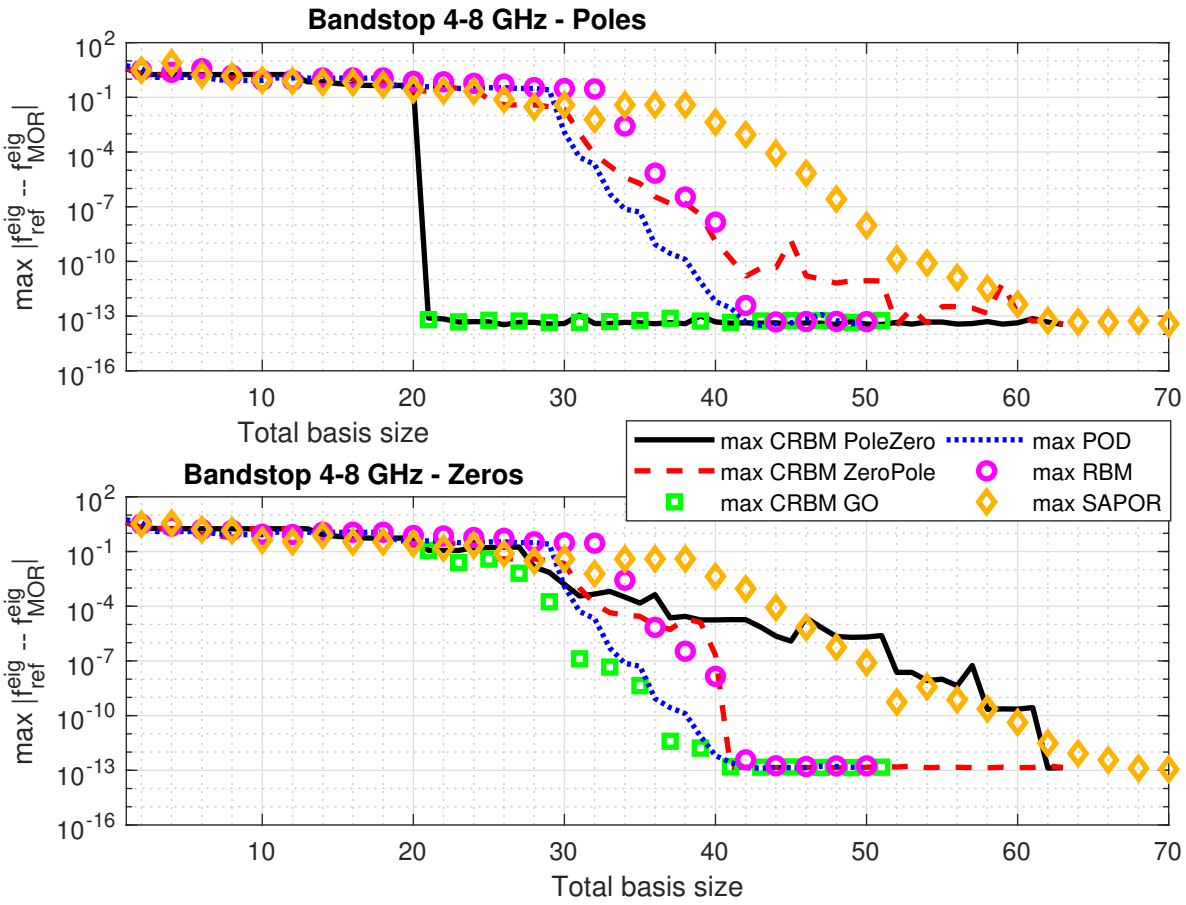

CRBM V2 Approach (ZeroPole) - Zeros
Total basis size
f (GHz)

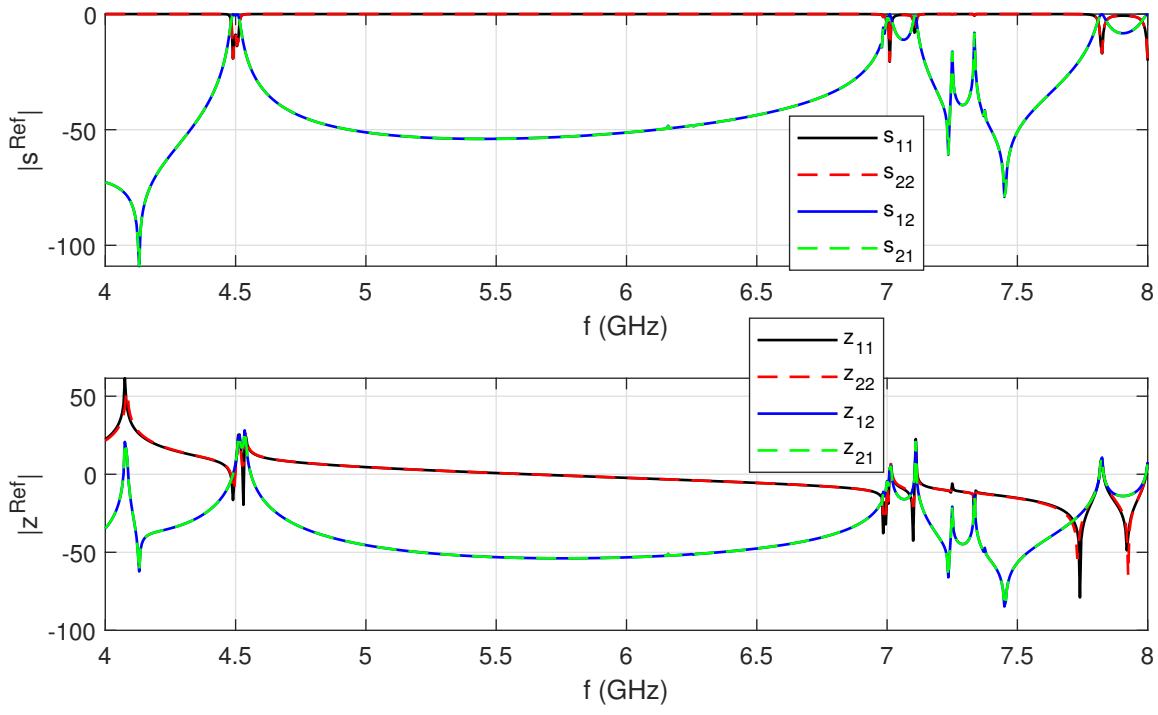

CRBM V2 Approach (PoleZero) - Zeros
Total basis size
f (GHz)

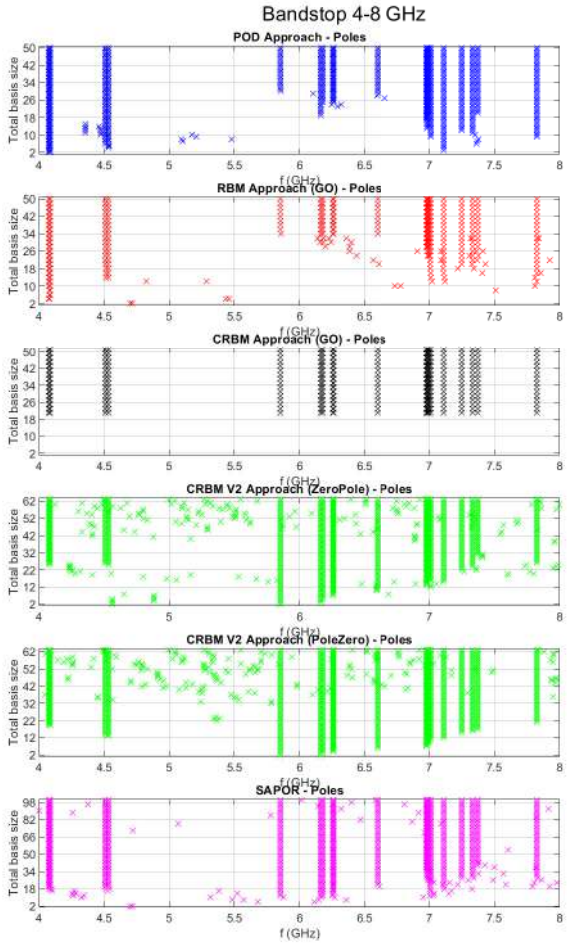

SAPOR - Zeros
Total basis size
f (GHz)

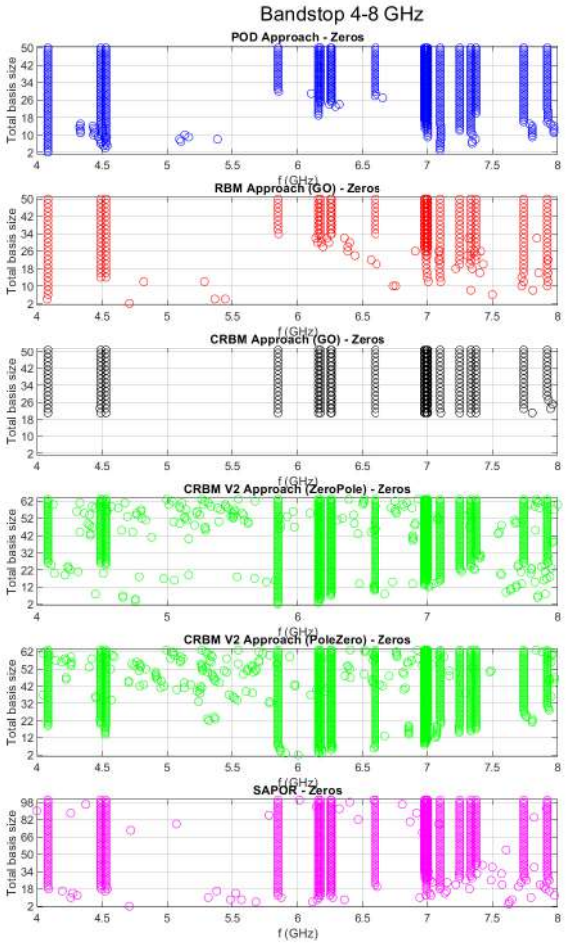
Bandstop 4-8 GHz

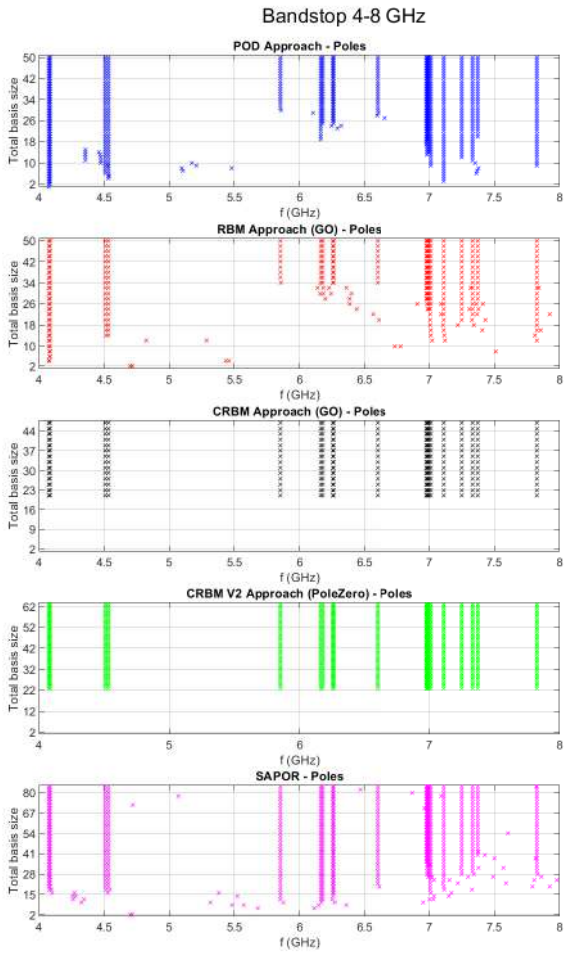


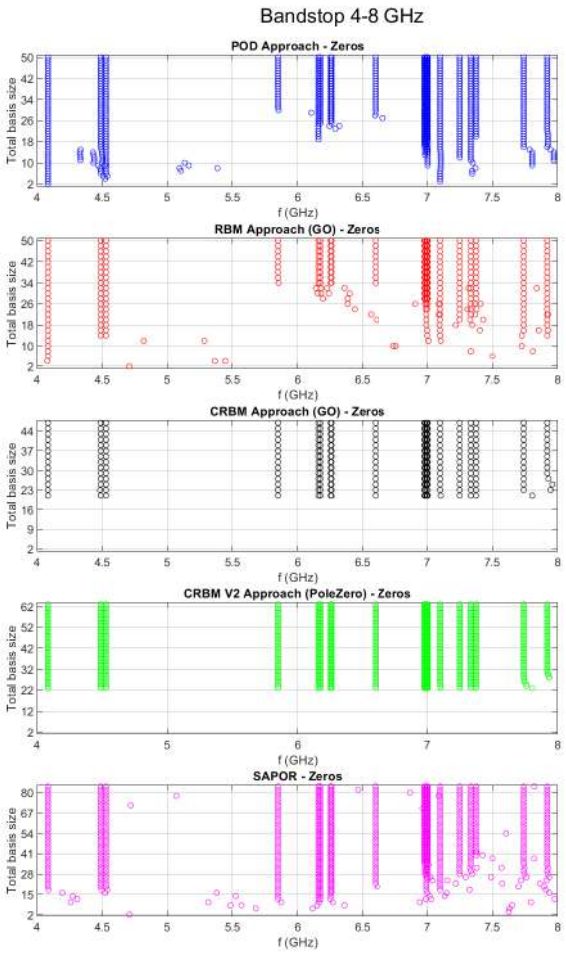

Bandstop 4-8 GHz - Poles
max |f_ref^eig -- f_MOR^eig|
Total basis size
Bandstop 4-8 GHz - Zeros
max |f_ref^eig -- f_MOR^eig|
Total basis size
max CRBM PoleZero
max CRBM ZeroPole
max CRBM GO
max POD
max RBM
max SAPOR


|s^Ref|
f (GHz)
s11
s22
s12
s21
|z^Ref|
f (GHz)
z11
z22
z12
z21


Bandstop 4-8 GHz
POD Approach - Poles
RBM Approach (GO) - Poles
CRBM Approach (GO) - Poles
CRBM V2 Approach (ZeroPole) - Poles
CRBM V2 Approach (PoleZero) - Poles
SAPOR - Poles
Total basis size
f (GHz)


Bandstop 4-8 GHz
POD Approach - Zeros
RBM Approach (GO) - Zeros
CRBM Approach (GO) - Zeros
CRBM V2 Approach (ZeroPole) - Zeros
CRBM V2 Approach (PoleZero) - Zeros
SAPOR - Zeros
Total basis size
f (GHz)


Bandstop 4-8 GHz
POD Approach - Poles
RBM Approach (GO) - Poles
CRBM Approach (GO) - Poles
CRBM V2 Approach (PoleZero) - Poles
SAPOR - Poles
Total basis size
f (GHz)


Bandstop 4-8 GHz
POD Approach - Zeros
RBM Approach (GO) - Zeros
CRBM Approach (GO) - Zeros
CRBM V2 Approach (PoleZero) - Zeros
SAPOR - Zeros
Total basis size
f (GHz)