
Raport 87

SLEPC: generalized eigenproblems tests

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1 Introduction

The aim of this report is to provide the results of SLEPC+MKL performance (computational time and number of iterations) as a function of the number of variables, number of eigenvalues required and the value of ϵ'' . The test structure: Lossy dielectric from Malgorzata Warecka Rep (Fig. 1 a)). The reference eigenvalues for $\epsilon_r = \epsilon' - j\epsilon''$ with $\epsilon'' \in \{1, 5, 10, 50\}$ are provided in Tab. 1.

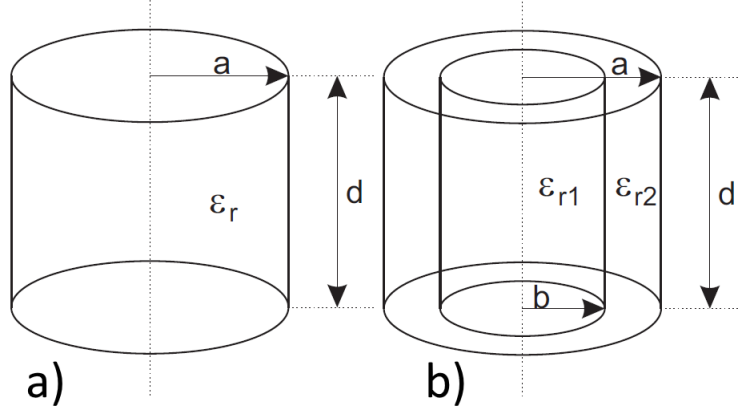


Figure 1: $d = 10\sqrt{2}\text{mm}$, $a = 10\text{mm}$, $b = 6.35\text{mm}$.

Comments:

- As can be seen on the error plots, some eigenvalues are degenerate.
- The reference eigenvalues are provided at the end of the Rep.
- The tolerance of SLEPC is set to $1e - 4$
- Shift is set to 6.4 GHz
- ncv is set to 60 (with the only exception being the test 2.9)

2 Results

2.1 $\epsilon'' = 1$, $n = 82768$, $\text{nev} = 20$

SLEPC time	30.1
Conversion from inventSIM to PETSC time	0.4
Solv time	18.1
Get eigenpair time	5.2
Display results time	6.3
<hr/>	
Number of iterations	1
Number of linear iterations	60
Number of requested eigenvalues	20
Number of variables	82768
epsilon''	1

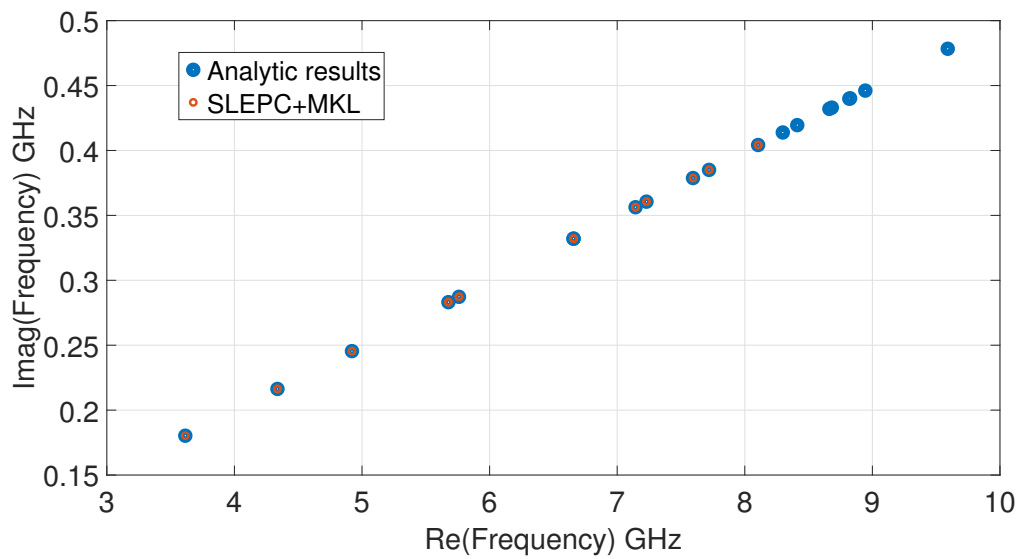


Figure 2: Eigenvalues (SLEPC, analytic results)

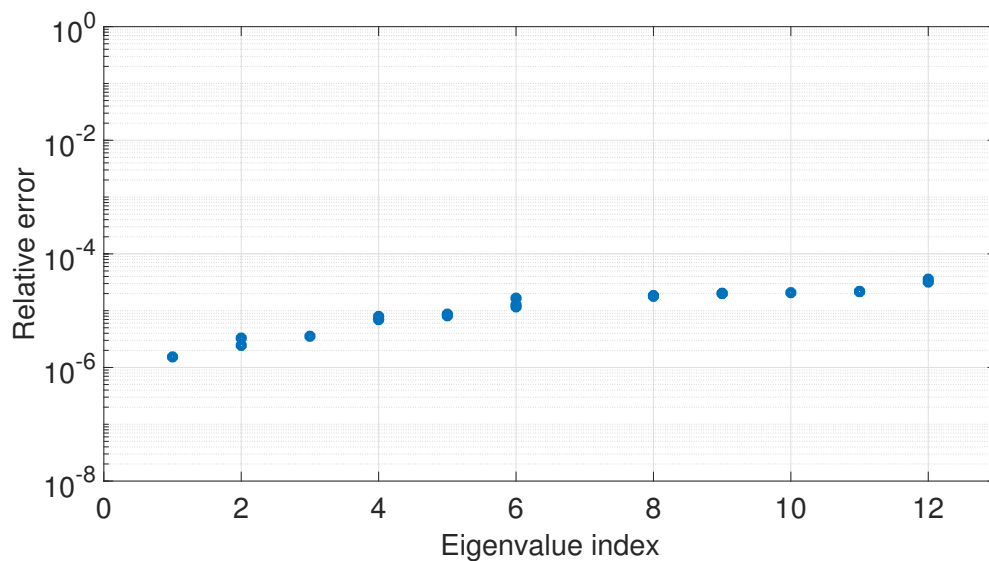


Figure 3: Eigenvalues error plot (SLEPC vs analytic results)

2.2 $\epsilon'' = 1$, $n = 82768$, $\text{nev} = 10$

SLEPC time	28.4
Conversion from inventSIM to PETSC time	0.5
Solv time	18.6
Get eigenpair time	2.6
Display results time	6.5
<hr/>	
Number of iterations	1
Number of linear iterations	60
Number of requested eigenvalues	10
Number of variables	82768
epsilon''	1

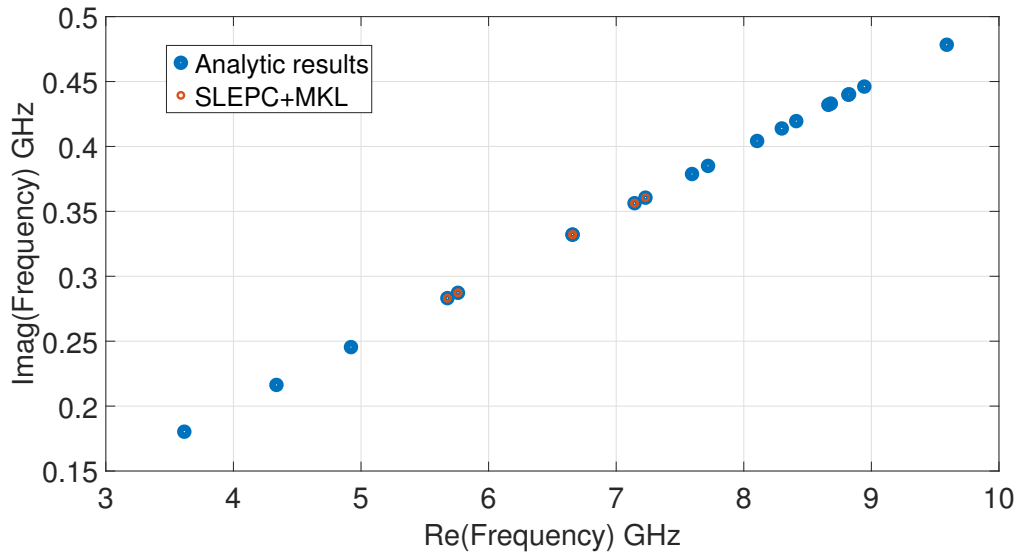


Figure 4: Eigenvalues (SLEPC, analytic results)

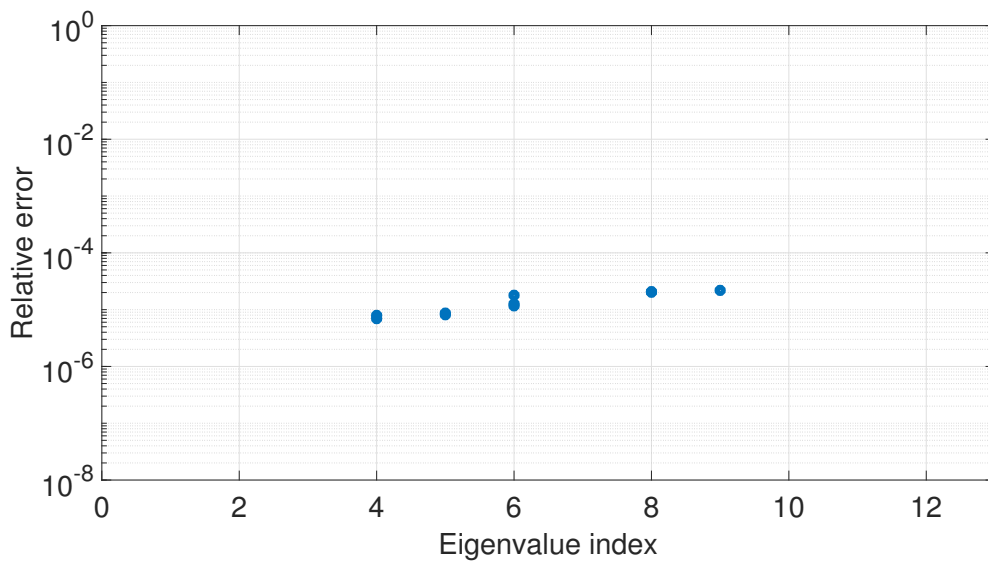


Figure 5: Eigenvalues error plot (SLEPC vs analytic results)

2.3 $\epsilon'' = 1$, $n = 125956$, $\text{nev} = 20$

SLEPC time	49.3
Conversion from inventSIM to PETSC time	0.7
Solv time	30.9
Get eigenpair time	7.9
Display results time	9.6
<hr/>	
Number of iterations	1
Number of linear iterations	60
Number of requested eigenvalues	20
Number of variables	125956
epsilon''	1

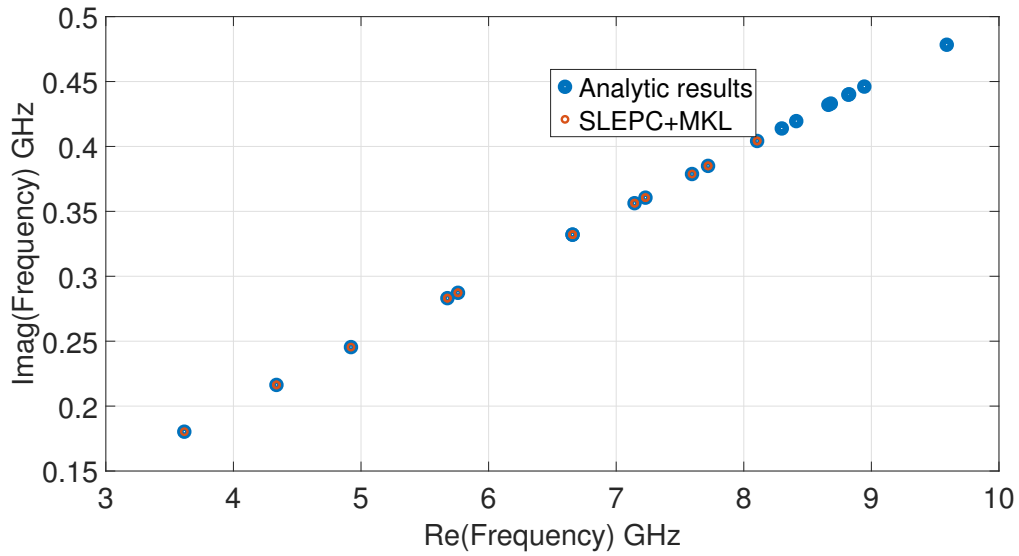


Figure 6: Eigenvalues (SLEPC, analytic results)

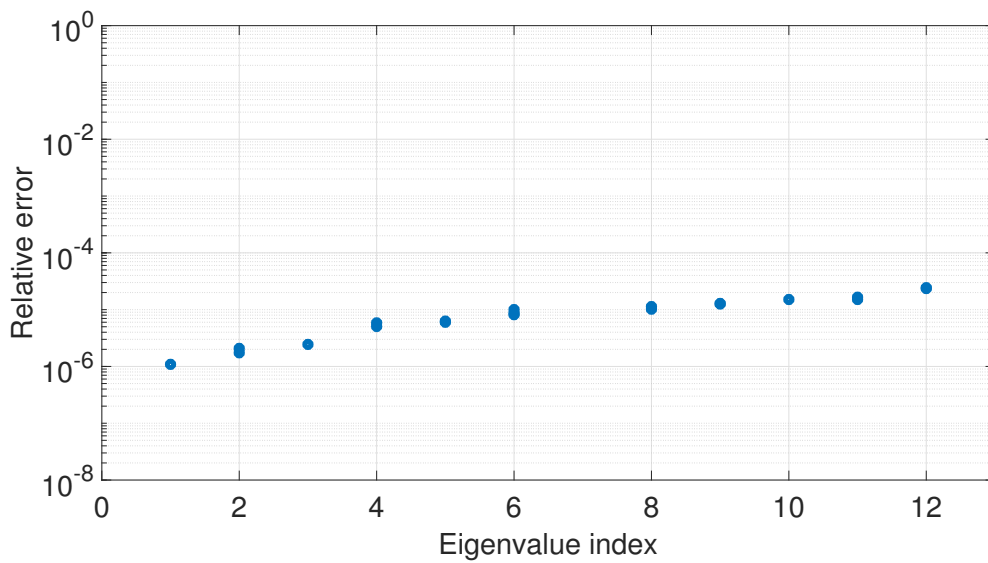


Figure 7: Eigenvalues error plot (SLEPC vs analytic results)

2.4 $\epsilon'' = 1$, $n = 125956$, $\text{nev} = 10$

SLEPC time	46.0
Conversion from inventSIM to PETSC time	0.7
Solv time	31.2
Get eigenpair time	4.1
Display results time	9.8
<hr/>	
Number of iterations	1
Number of linear iterations	60
Number of requested eigenvalues	10
Number of variables	125956
epsilon''	1

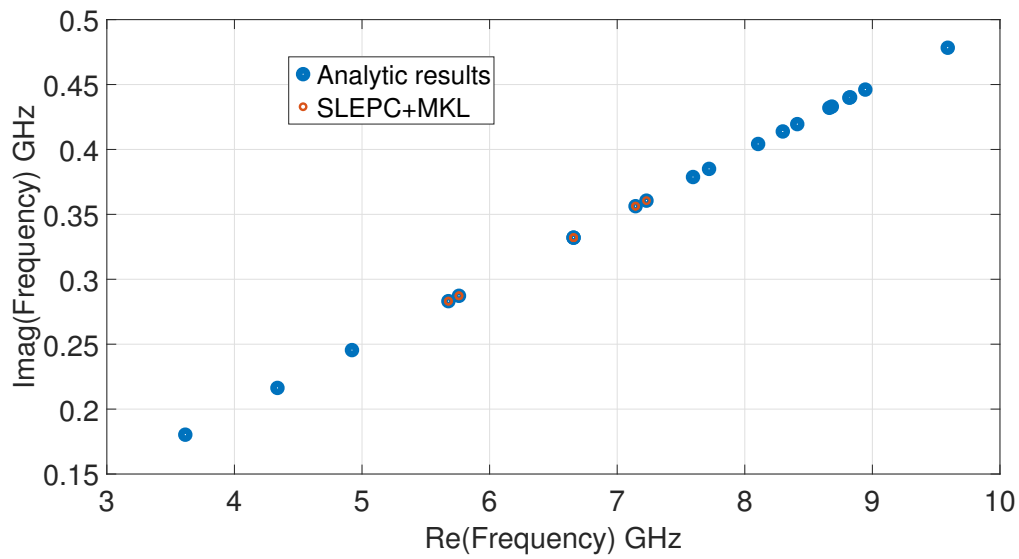


Figure 8: Eigenvalues (SLEPC, analytic results)

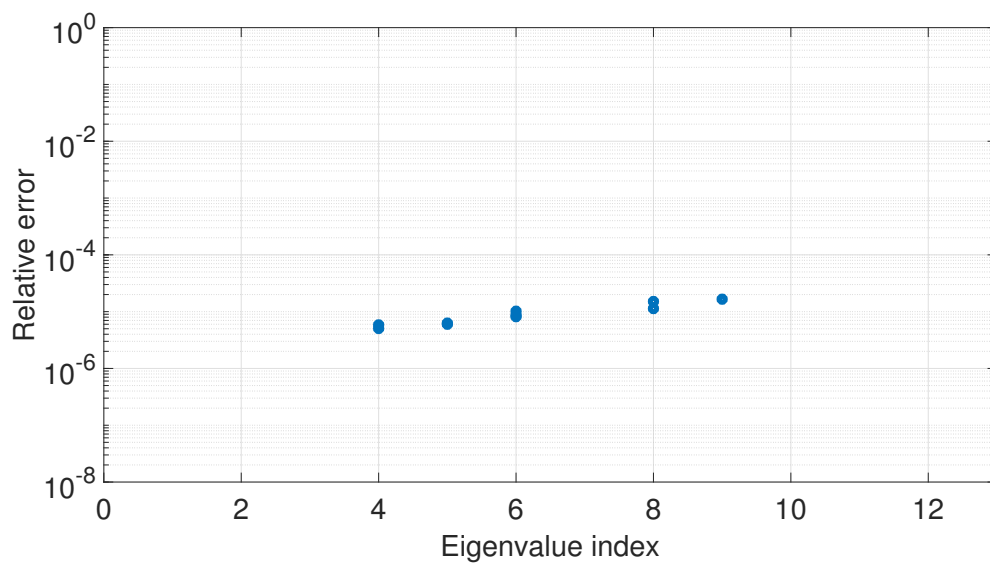


Figure 9: Eigenvalues error plot (SLEPC vs analytic results)

2.5 $\epsilon'' = 10$, $n = 82768$, $nev = 20$

SLEPC time	40.8
Conversion from inventSIM to PETSC time	0.4
Solv time	28.0
Get eigenpair time	5.4
Display results time	6.8
<hr/>	
Number of iterations	2
Number of linear iterations	103
Number of requested eigenvalues	20
Number of variables	82768
epsilon''	10

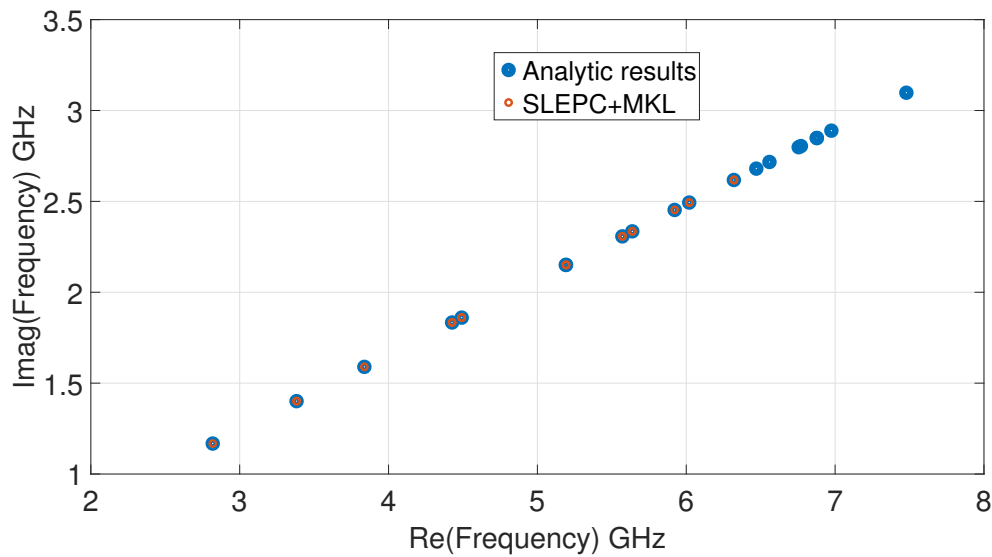


Figure 10: Eigenvalues (SLEPC, analytic results)

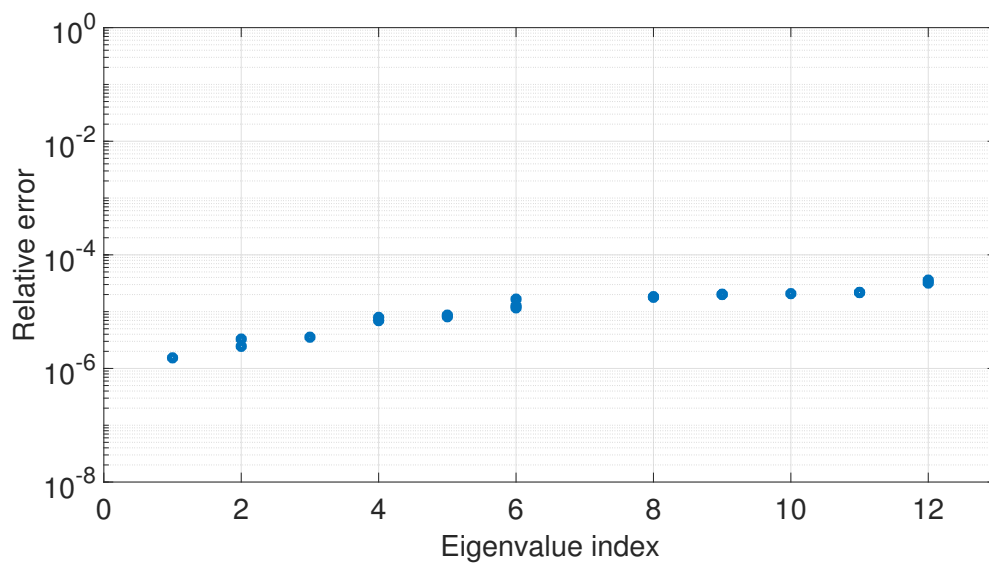


Figure 11: Eigenvalues error plot (SLEPC vs analytic results)

2.6 $\epsilon'' = 10$, $n = 82768$, $nev = 10$

SLEPC time	26.3
Conversion from inventSIM to PETSC time	0.5
Solv time	18.6
Get eigenpair time	2.6
Display results time	4.5
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Number of iterations	1
Number of linear iterations	60
Number of requested eigenvalues	10
Number of variables	82768
epsilon''	10

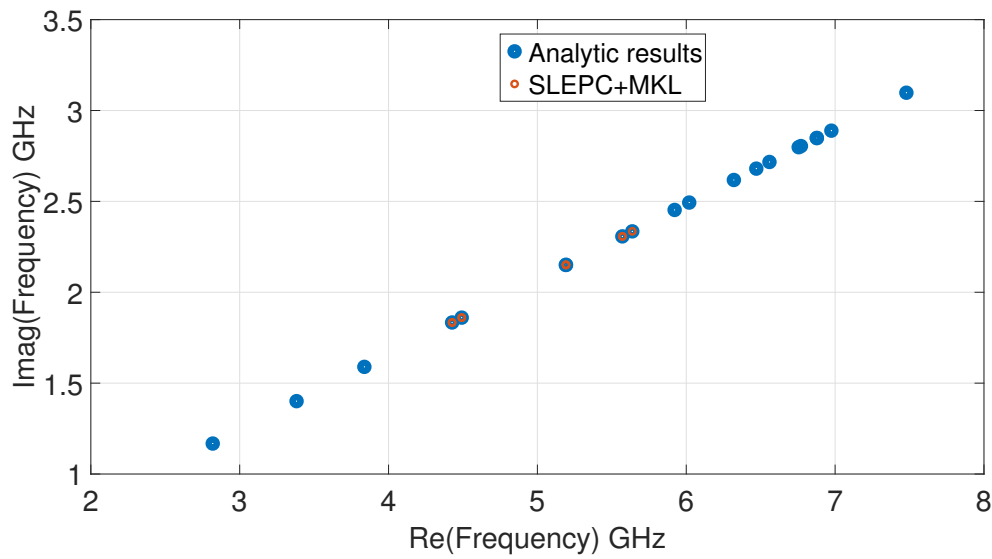


Figure 12: Eigenvalues (SLEPC, analytic results)

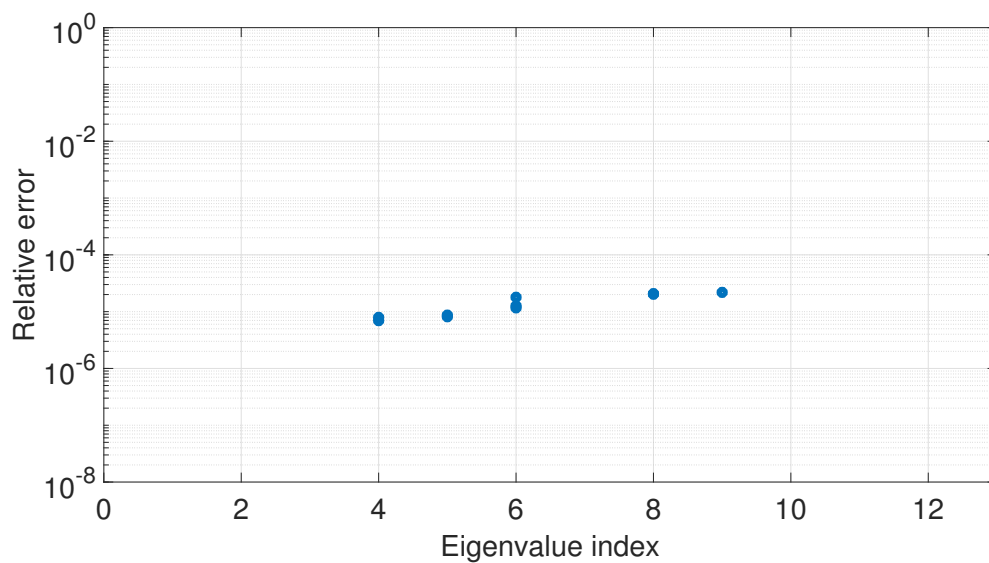


Figure 13: Eigenvalues error plot (SLEPC vs analytic results)

2.7 $\epsilon'' = 10$, $n = 125956$, $\text{nev} = 20$

SLEPC time	64.1
Conversion from inventSIM to PETSC time	0.6
Solv time	47.1
Get eigenpair time	7.9
Display results time	8.3
<hr/>	
Number of iterations	2
Number of linear iterations	103
Number of requested eigenvalues	20
Number of variables	125956
epsilon''	10

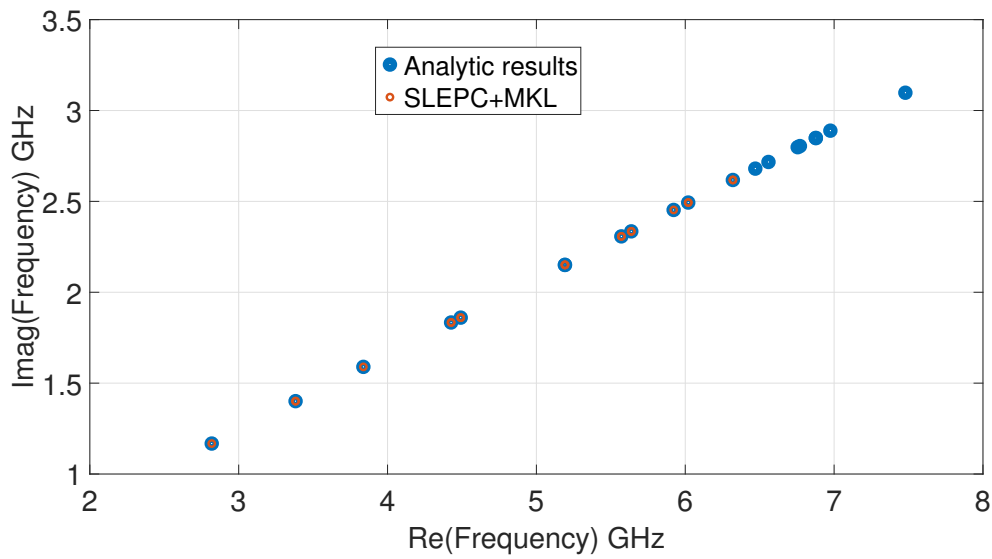


Figure 14: Eigenvalues (SLEPC, analytic results)

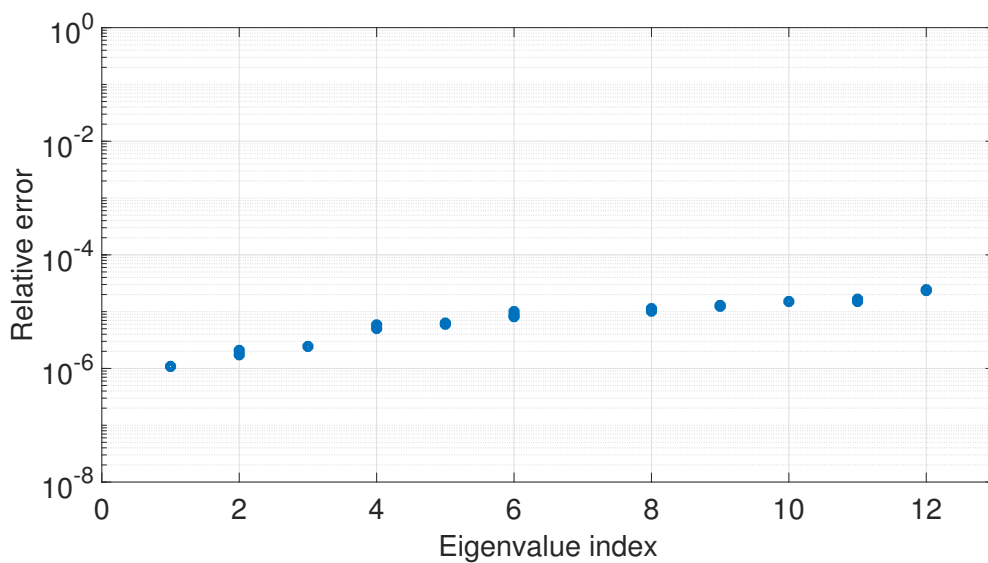


Figure 15: Eigenvalues error plot (SLEPC vs analytic results)

2.8 $\epsilon'' = 10$, $n = 125956$, $\text{nev} = 10$

SLEPC time	43.0
Conversion from inventSIM to PETSC time	0.7
Solv time	31.0
Get eigenpair time	4.2
Display results time	6.9
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Number of iterations	1
Number of linear iterations	60
Number of requested eigenvalues	10
Number of variables	125956
epsilon''	10

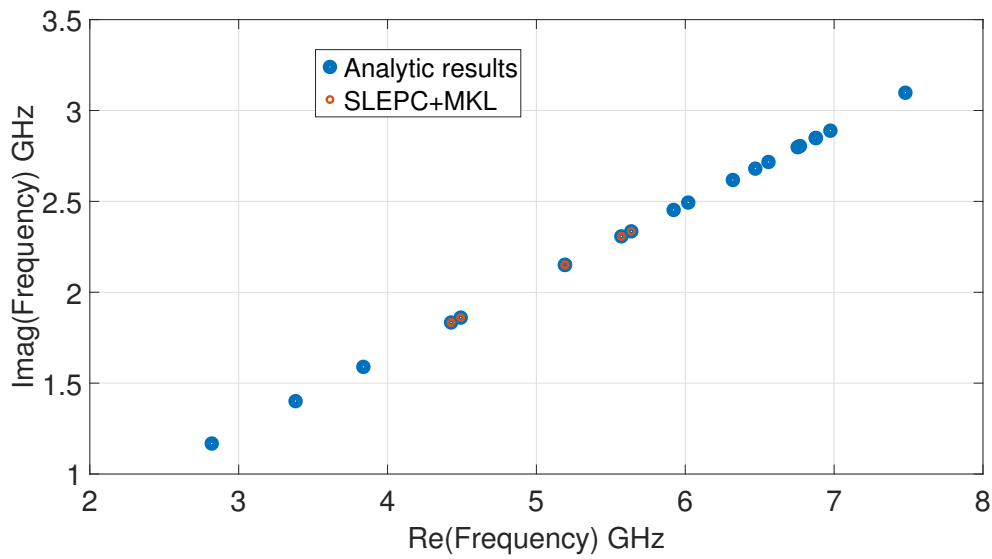


Figure 16: Eigenvalues (SLEPC, analytic results)

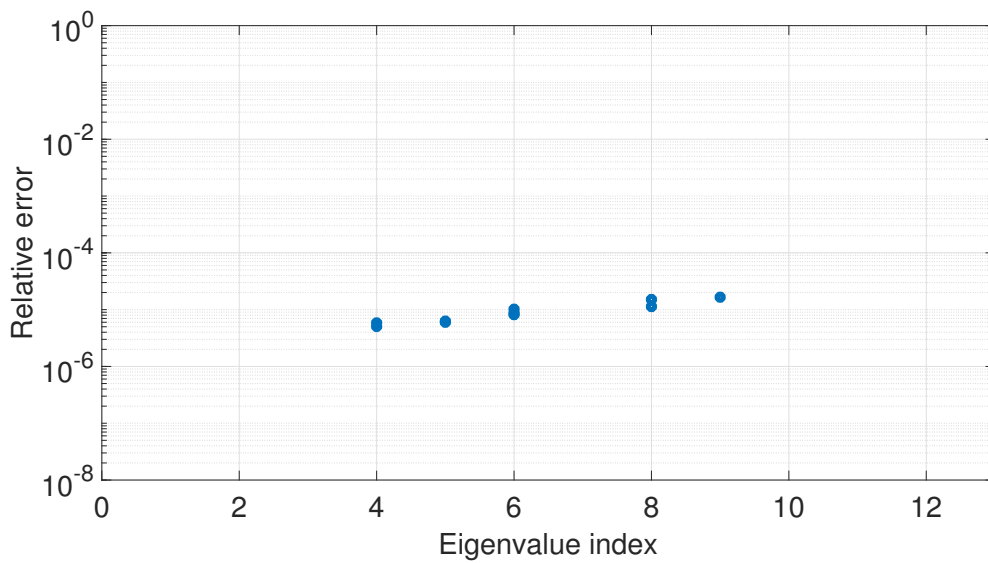


Figure 17: Eigenvalues error plot (SLEPC vs analytic results)

2.9 ncv set to 30 ($1.5 \cdot nev$)

The aim of the last numerical test is to check the number of Arnoldi iterations assuming $ncv = 30$ which is ($1.5 \cdot nev$). It can be seen that the number of iterations significantly increased.

SLEPC time	123.0
Conversion from inventSIM to PETSC time	0.7
Solv time	106.1
Get eigenpair time	7.9
Display results time	8.1
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Number of iterations	15
Number of linear iterations	271
Number of requested eigenvalues	20
Number of variables	125956
epsilon"	10

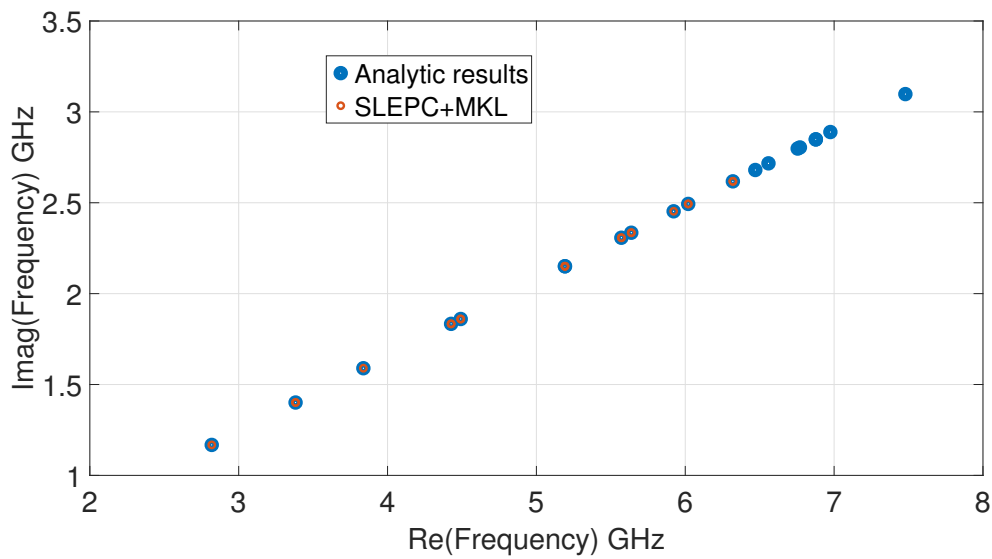


Figure 18: Eigenvalues (SLEPC, analytic results)

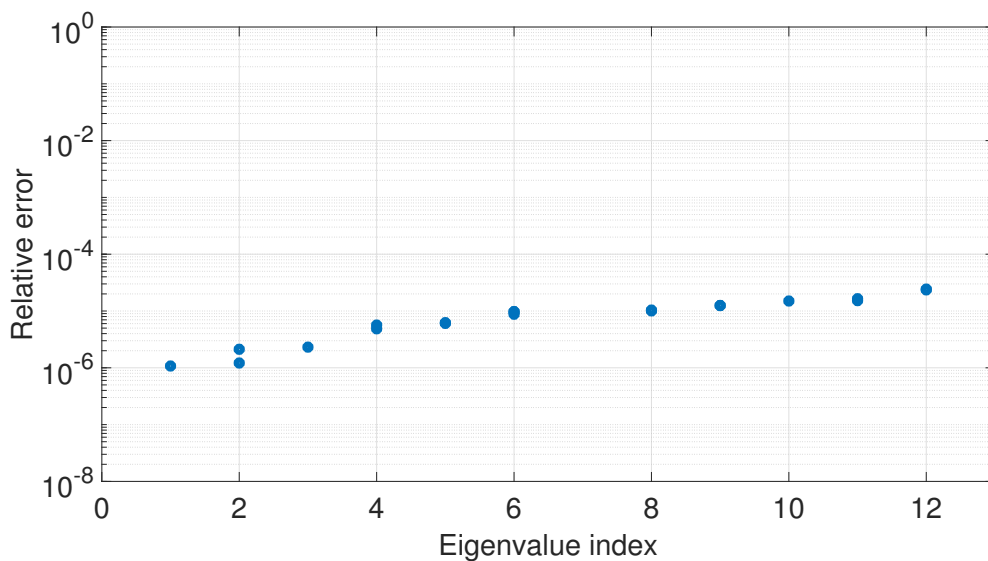


Figure 19: Eigenvalues error plot (SLEPC vs analytic results)

2.10 Tolerance set to $1e-8$ (comparison to $1e-4$ - results in brackets)

SLEPC time	74.4 (40.0)
Conversion from inventSIM to PETSC time	0.4
Solv time	63.4 (27.6)
Get eigenpair time	5.2
Display results time	5.2
<hr/>	
Number of iterations	5 (2)
Number of linear iterations	263 (103)
Number of requested eigenvalues	20
Number of variables	82768
epsilon"	10

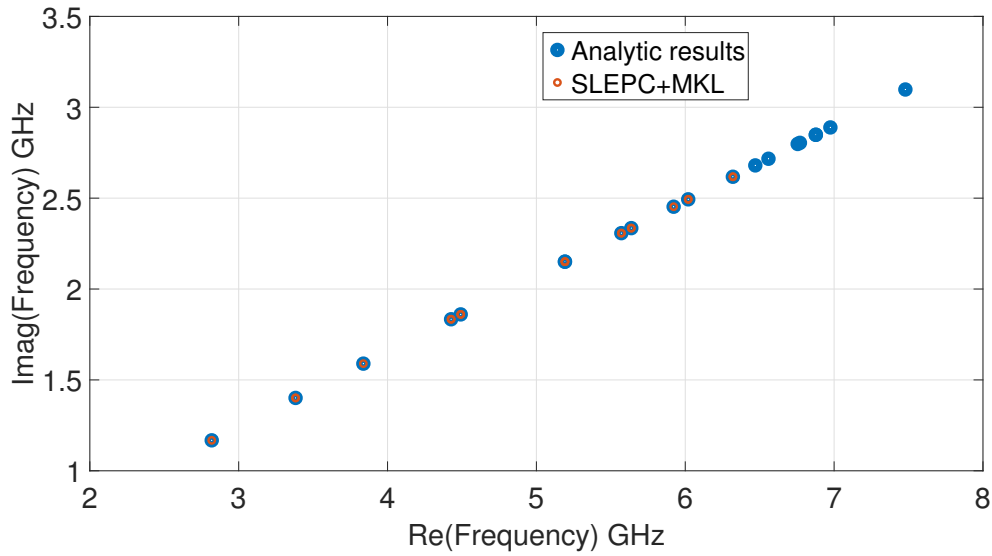


Figure 20: Eigenvalues (SLEPC, analytic results)

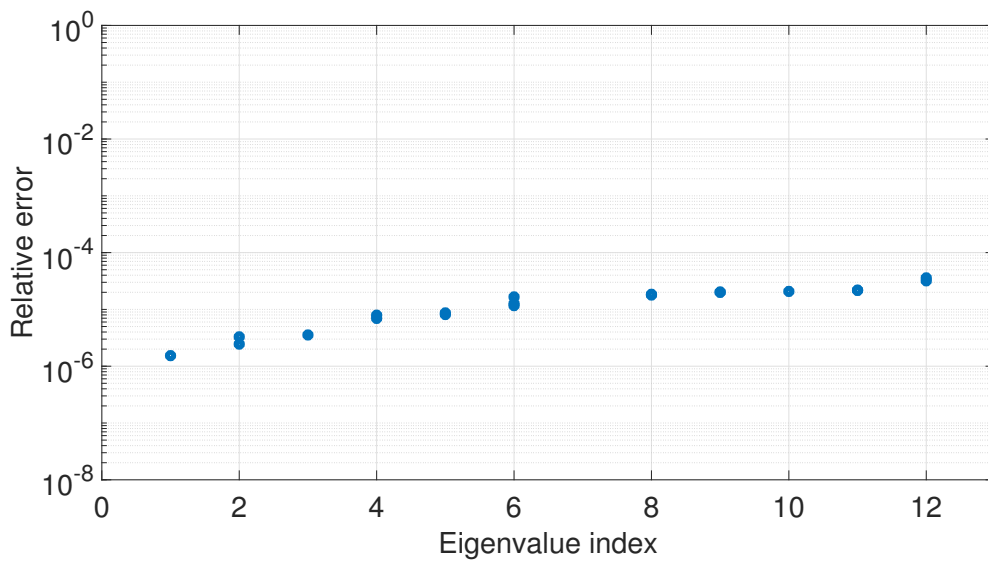


Figure 21: Eigenvalues error plot (SLEPC vs analytic results)

2.11 epsilon'' = 50 (comparison to epsilon'' = 10 - results in brackets)

SLEPC time	348.3 (123.0)
Conversion from inventSIM to PETSC time	0.7
Solv time	329.9 (106.1)
Get eigenpair time	8.5
Display results time	9.0
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Number of iterations	16 (15)
Number of linear iterations	833 (271)
Number of requested eigenvalues	20
Number of variables	125956
epsilon''	50

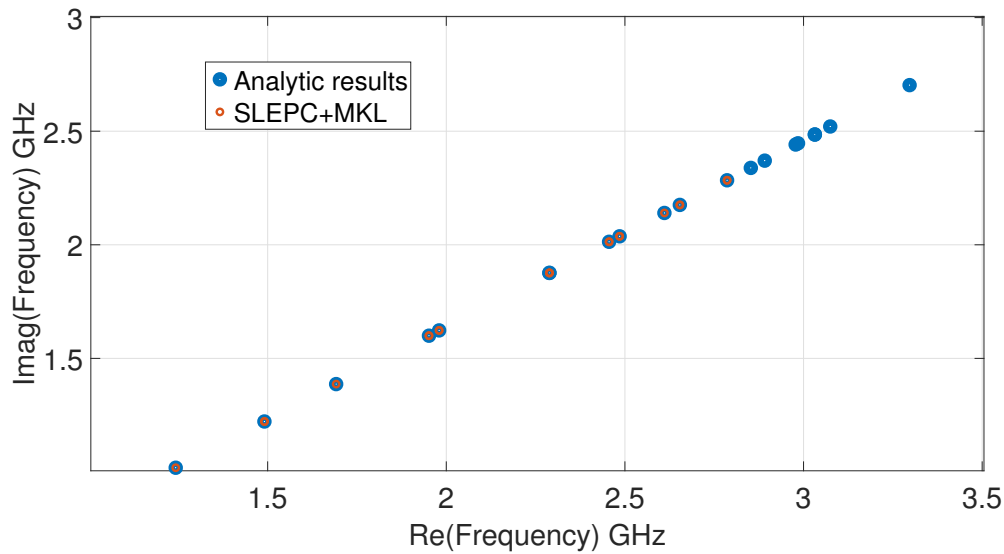


Figure 22: Eigenvalues (SLEPC, analytic results)

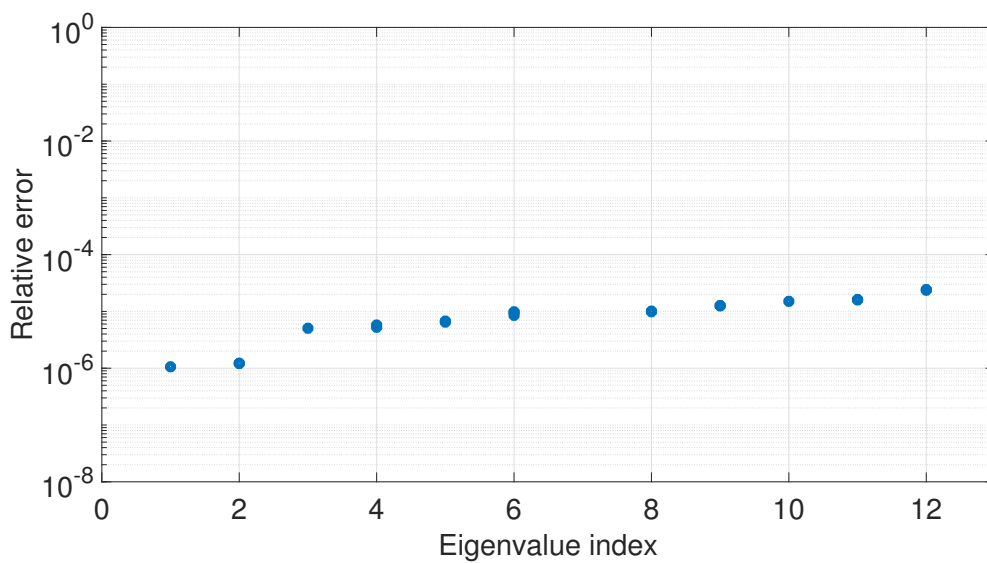


Figure 23: Eigenvalues error plot (SLEPC vs analytic results)

2.12 $n = 701846$ (compression to $n = 125956$)

SLEPC time	606.4 (64.1)
Conversion from inventSIM to PETSC time	3.8 (0.6)
Solv time	495.3 (47.1)
Get eigenpair time	49.5 (7.9)
Display results time	55.9 (8.3)
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Number of iterations	2
Number of linear iterations	103
Number of requested eigenvalues	20
Number of variables	701846
epsilon"	10

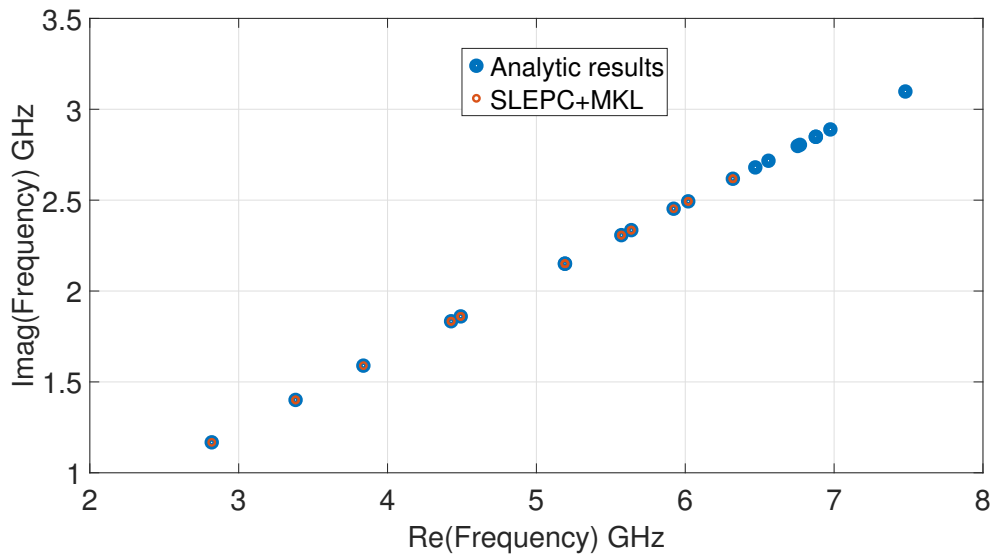


Figure 24: Eigenvalues (SLEPC, analytic results)

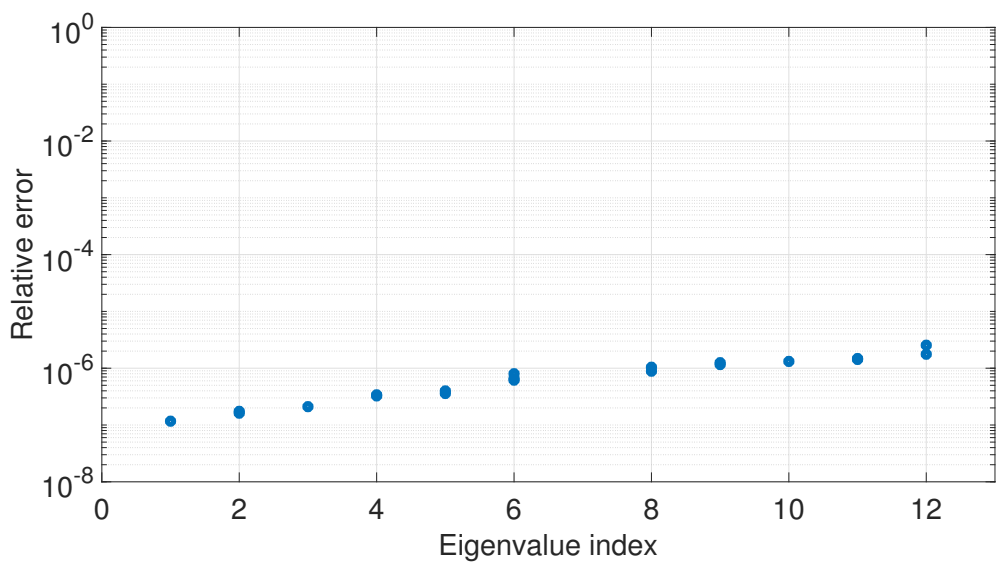


Figure 25: Eigenvalues error plot (SLEPC vs analytic results)

3 Conclusions

From the above results it can be seen that the number of iterations (an in effect - the computational time) depends on ϵ'' and ncv parameter. Test 2.9 shows that decreasing ncv to $1.5 \cdot ncv$ results in as many as 15 iterations and 271 linear iterations.

Table 1: A resonance frequency of the homogeneous resonator as a function of the loss coefficient.

ϵ''	1	5
TM_{010}	3.614968939 + 0.180298821i	3.339803162 + 0.788420577i
TE_{111}	4.337174043 + 0.216319249i	4.007035144 + 0.945932682i
TM_{011}	4.921274929 + 0.245451643i	4.546675185 + 1.073324415i
TE_{211}	5.677131457 + 0.283150457i	5.244997097 + 1.238175856i
TM_{110}	5.759876437 + 0.287277414i	5.321443659 + 1.256222442i
TM_{111}	6.657861749 + 0.332064990i	6.151075735 + 1.452072008i
TE_{011}	6.657861749 + 0.332064990i	6.151075735 + 1.452072008i
TE_{311}	7.143795708 + 0.356301248i	6.600021162 + 1.558053647i
TE_{112}	7.229378824 + 0.360569759i	6.679089825 + 1.576719226i
TM_{012}	7.594194258 + 0.378765155i	7.016136079 + 1.656285054i
TM_{210}	7.719942531 + 0.385036928i	7.132312590 + 1.683710608i
TE_{212}	8.104484011 + 0.404216173i	7.487583374 + 1.767578663i
TM_{020}	8.297862124 + 0.413861027i	7.666241848 + 1.809754208i
TM_{211}	8.411210328 + 0.419514339i	7.770962165 + 1.834475321i
TE_{411}	8.662896020 + 0.432067319i	8.003489935 + 1.889367682i
TE_{121}	8.682165324 + 0.433028388i	8.021292490 + 1.893570295i
TE_{012}	8.825400373 + 0.440172325i	8.153624712 + 1.924809695i
TM_{112}	8.819294902 + 0.439867811i	8.147983980 + 1.923478098i
TM_{021}	8.944577258 + 0.446116346i	8.263730039 + 1.950802036i
TM_{310}	9.590752646 + 0.478344745i	8.860719567 + 2.091732147i

ϵ''	10	50
TM_{010}	2.818916816 + 1.167633576i	1.242661241 + 1.018738535i
TE_{111}	3.382085171 + 1.400905547i	1.490922376 + 1.222263982i
TM_{011}	3.837561231 + 1.589569908i	1.691709587 + 1.386870122i
TE_{211}	4.426970632 + 1.833711276i	1.951538545 + 1.599878915i
TM_{110}	4.491494345 + 1.860437873i	1.979982491 + 1.623197373i
TM_{111}	5.191734358 + 2.150486783i	2.288668834 + 1.876259642i
TE_{011}	5.191734358 + 2.150486783i	2.288668834 + 1.876259642i
TE_{311}	5.570660825 + 2.307443265i	2.455710739 + 2.013201247i
TE_{112}	5.637397687 + 2.335086578i	2.485130306 + 2.037319523i
TM_{012}	5.921877133 + 2.452921823i	2.610537192 + 2.140128578i
TM_{210}	6.019934386 + 2.493538467i	2.653763706 + 2.175565843i
TE_{212}	6.319796006 + 2.617745217i	2.785951507 + 2.283933918i
TM_{020}	6.470590334 + 2.680206273i	2.852426071 + 2.338430025i
TM_{211}	6.558978137 + 2.716817699i	2.891390008 + 2.370372813i
TE_{411}	6.755240135 + 2.798112081i	2.977908055 + 2.441300645i
TE_{121}	6.770266147 + 2.804336059i	2.984531962 + 2.446730950i
TE_{012}	6.877198428 + 2.848628860i	3.031670849 + 2.485375594i
TM_{112}	6.877198428 + 2.848628860i	3.031670849 + 2.485375594i
TM_{021}	6.974892363 + 2.889095012i	3.074737202 + 2.520681558i
TM_{310}	7.478773501 + 3.097809414i	3.296862792 + 2.702780984i