EDISON

Electromagnetic Design of
flexIble SensOrs

FNP Team-Tech

Report 89 ARPACK+ABC

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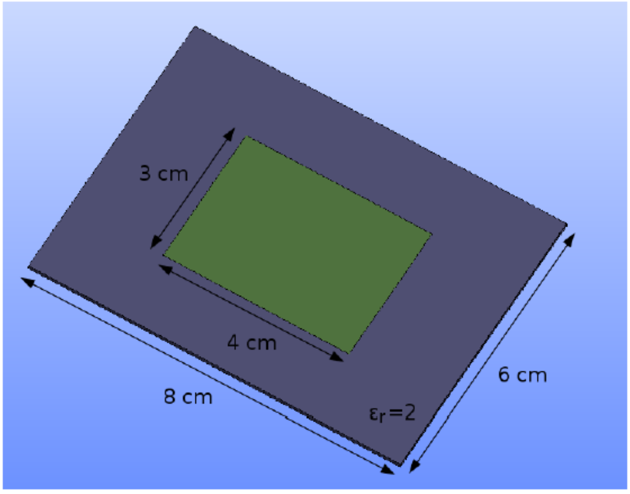

Fig. 1. A cavity backed patch antenna geometry. The cavity is totally filled with Teflon ($\epsilon_r = 2.0$) and its dimensions are $0.1 \times 6 \times 8\ cm^3$, while the surface of the patch is $3 \times 4\ cm^2$.

Figure 1: Cavity backed patch antenna - **the ABC placement is not defined.**

1 Test Structure

TABLE I
FIRST LOWEST EIGENVALUES OF THE PATCH ANTENNA COMPUTED WITH AND WITHOUT CONSTRAINED EQUATIONS.

Mode	Unconstrained		Constrained		HFSS
No.	$f_r + j\frac{f_r}{2Q}$	err(e)	$f_r + j\frac{f_r}{2Q}$	err(e)	f_r
1	3.3e-07+j4.1e-10	0.13	3.32 +j0.67	1.6e-15	3.30
2	2.6e-07+j2.7e-07	0.47	4.62 +j0.52	2.3e-15	4.60
3	5.9e-08+j7.7e-07	0.29	6.47 +j1.08	1.4e-15	-
4	3.32 +j0.67	0.65	10.07 +j1.57	1.4e-15	-
5	4.62 +j0.52	0.13	10.77 +j1.94	6.7e-15	-
6	6.47 +j1.08	0.03	12.52 +j1.96	4.3e-15	-

Figure 2: Cavity backed patch antenna - the reference results from the paper.

- Defined in:
  Zekios, C., P. Allilomes, and G. Kyriacou. "Eigenanalysis of open-radiating microwave structures with efficient suppression of spurious modes." 2015 IEEE International Conference on Computational Electromagnetics. IEEE, 2015.
- substrate: teflon, $\epsilon_r = 2$
- **The ABC placement is not defined.**

2 Linearization

The original FEM equation:

$$\mathbf{Se} - k_0^2\mathbf{Me} + jk_0\mathbf{Re} = 0 \tag{1}$$

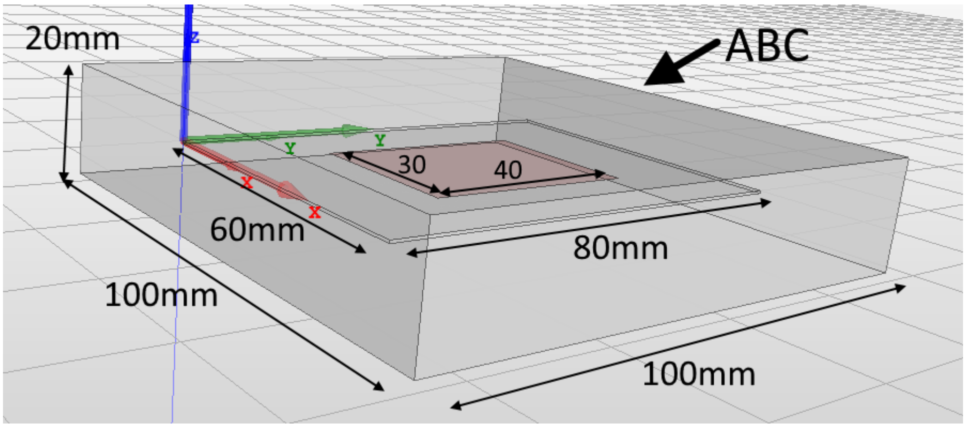

Figure 3: Cavity backed patch antenna - model 1

Assuming $\lambda = l_0$, we obtain the characteristic polynomial:

$$P(\lambda) = -\lambda^2\mathbf{M} + \lambda\mathbf{R} + \mathbf{S} = 0 \tag{2}$$

Four linearization formulas have been considered, symmetric and non-symmetric, taken from eq. (28) and (29):

- Zekios, Constantinos L., Peter C. Allilomes, and George A. Kyriacou. "DC and Imaginary spurious modes suppression for both unbounded and lossy structures." IEEE Transactions on Microwave Theory and Techniques 63.7 (2015): 2082-2093.

Note that the two variants are considered, with and without j.

$$\left(\lambda\begin{bmatrix}\mathbf{0} & -\mathbf{M}\\ -\mathbf{M} & \mathbf{R}\end{bmatrix} + \begin{bmatrix}\mathbf{M} & \mathbf{0}\\ \mathbf{0} & \mathbf{S}\end{bmatrix}\right)\begin{bmatrix}\mathbf{u}\\ \mathbf{e}\end{bmatrix} = \begin{bmatrix}\mathbf{0}\\ \mathbf{0}\end{bmatrix}, \tag{3}$$

$$\left(\lambda\begin{bmatrix}\mathbf{0} & -\mathbf{M}\\ -\mathbf{M} & j\mathbf{R}\end{bmatrix} + \begin{bmatrix}\mathbf{M} & \mathbf{0}\\ \mathbf{0} & \mathbf{S}\end{bmatrix}\right)\begin{bmatrix}\mathbf{u}\\ \mathbf{e}\end{bmatrix} = \begin{bmatrix}\mathbf{0}\\ \mathbf{0}\end{bmatrix}, \tag{4}$$

$$\left(\lambda\begin{bmatrix}\mathbf{R} & -\mathbf{M}\\ -\mathbf{I} & \mathbf{0}\end{bmatrix} + \begin{bmatrix}\mathbf{S} & \mathbf{0}\\ \mathbf{0} & \mathbf{I}\end{bmatrix}\right)\begin{bmatrix}\mathbf{u}\\ \mathbf{e}\end{bmatrix} = \begin{bmatrix}\mathbf{0}\\ \mathbf{0}\end{bmatrix}, \tag{5}$$

$$\left(\lambda\begin{bmatrix}j\mathbf{R} & -\mathbf{M}\\ -\mathbf{I} & \mathbf{0}\end{bmatrix} + \begin{bmatrix}\mathbf{S} & \mathbf{0}\\ \mathbf{0} & \mathbf{I}\end{bmatrix}\right)\begin{bmatrix}\mathbf{u}\\ \mathbf{e}\end{bmatrix} = \begin{bmatrix}\mathbf{0}\\ \mathbf{0}\end{bmatrix}. \tag{6}$$

3 Results obtained using eigs - model 1

In the first model the ABC is placed on the 100× 200 mm box surface. The results (in GHz) obtained using *eigs*() function, using shift: $\sigma = 83.833800878067265$, corresponding to $f = 4GHz$, $n = 53000$. The subsequent tables correspond to the formulas: (3)-(6).

2.025202836472777 - 1.425063530344964i
2.489637529055578 - 0.025000996311855i
3.239086939318947 - 0.040135359711567i
3.494418018647265 - 1.647021575824312i
4.138376613564292 - 0.032471151536757i
4.248121097134841 - 2.173780778262850i
4.980437311941355 - 0.045604672249391i
4.974782027763423 - 1.858679258787530i
5.501896233559213 - 1.929901922833569i
6.010288695891667 - 0.034122886108341i

3.775982525159236
3.832543614928898
3.835397186454839
3.855782188625494
3.951018114516339
3.957888436111936
4.110820604645940
4.157645582254611
4.258205246335582
4.303294708847684

2.025202836465801 - 1.425063530360421i
2.489637529055176 - 0.025000996311375i
3.239086939318885 - 0.040135359711266i
3.494418018639205 - 1.647021575824692i
4.138376613564502 - 0.032471151536578i
4.248121097128102 - 2.173780778276951i
4.980437311940851 - 0.045604672250089i
4.974782027715688 - 1.858679258801808i
5.501896233528012 - 1.929901922824393i
6.010288695892004 - 0.034122886108579i

3.775982525159452
3.832543614929022
3.835397186454190
3.855782188624795
3.951018114516285
3.957888436110809
4.110820604646168
4.157645582254497
4.258205246335123
4.303294708846614

4 Results obtained using eigs - model 2

In the second model the boundary conditions are composed of PEC (patch and ground) and ABC (rest of BC).

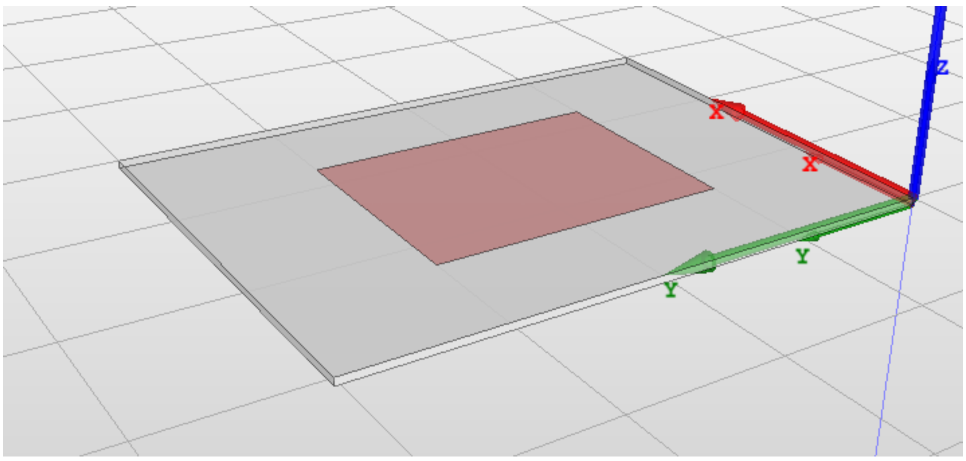

Figure 4: Cavity backed patch antenna - model 2

2.244329175010271 - 0.403482521835863i
3.006194390127013 - 0.521780577672458i
3.747612795119731 - 0.753575647377612i
4.784490180508920 - 0.616222939193018i
5.646254437343624 - 0.926137854679338i
6.409574450608256 - 0.779661533756349i
6.768974026160953 - 1.020401837530371i
7.402520238760083 - 0.768186314457868i

2.091076057752655
2.789436104941284
3.415505541753653
4.452560102932463
5.157743134286139
5.905818172757035
6.147183273341259
6.835572118868221
7.223280094025505
7.419795104254950

5 Results obtained using eigs - model 3

In the second model the boundary conditions are composed of PEC (ground) and ABC (rest of BC).

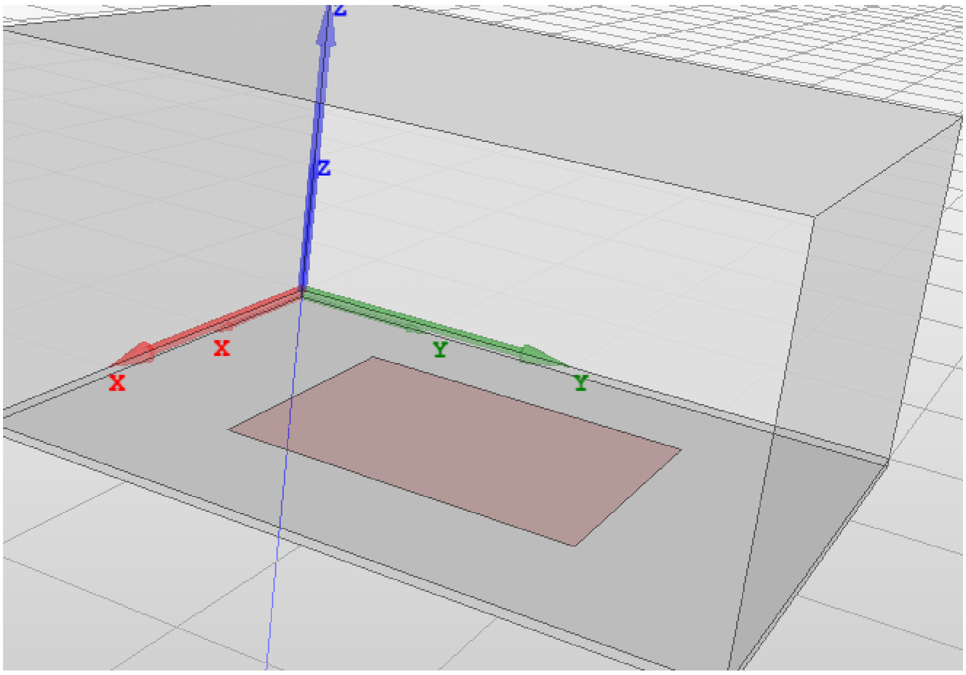

Figure 5: Cavity backed patch antenna - model 2

2.312339110178794 + 0.385539722104084i
2.458871141210532 + 1.552041104713652i
2.456076989624543 + 1.558230453147993i
3.066336300241635 + 0.481090082540569i
3.921743745138881 + 0.621716321025134i
3.982543755851051 + 1.699220200745956i
3.983965904668688 + 1.720330881217864i
4.857229727663196 + 0.498160989089874i
5.311050220310877 + 1.833194875063340i
5.845200790398373 + 0.683098752834095i

6 Cavity backed patch antenna - Sparams

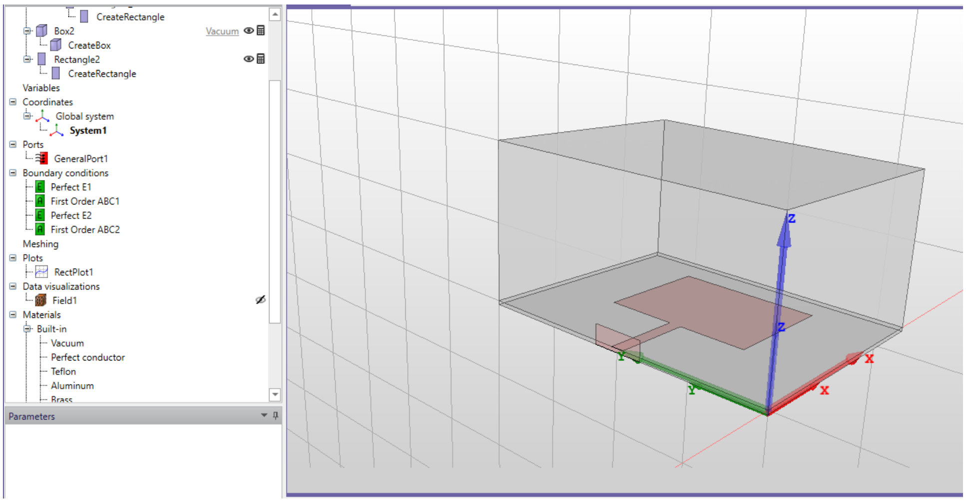

Figure 6: Cavity backed patch antenna - with excitation

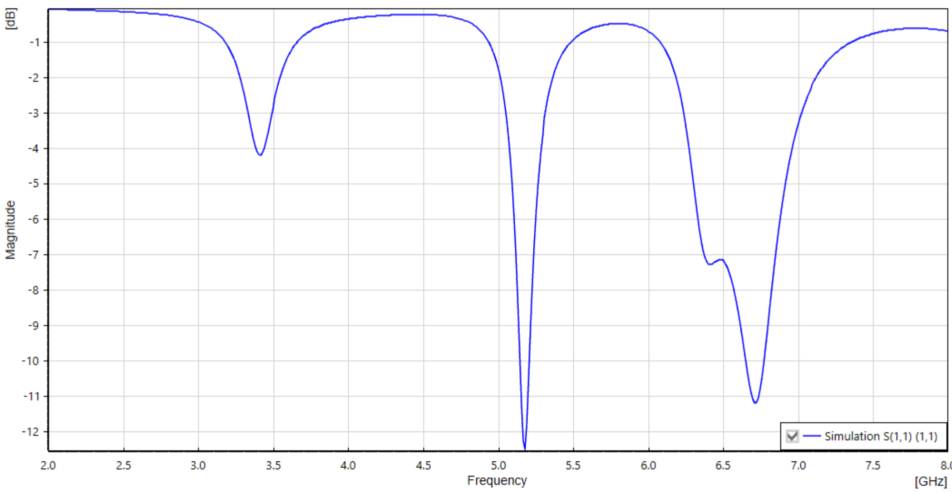

Figure 7: Cavity backed patch antenna, S-params, **GENERALIZED** waveguide excitation

Resonances from the S-plot in GHz (similar to the results obtained using model 2, and linearization (5)):

3.41
5.18
6.41
6.72

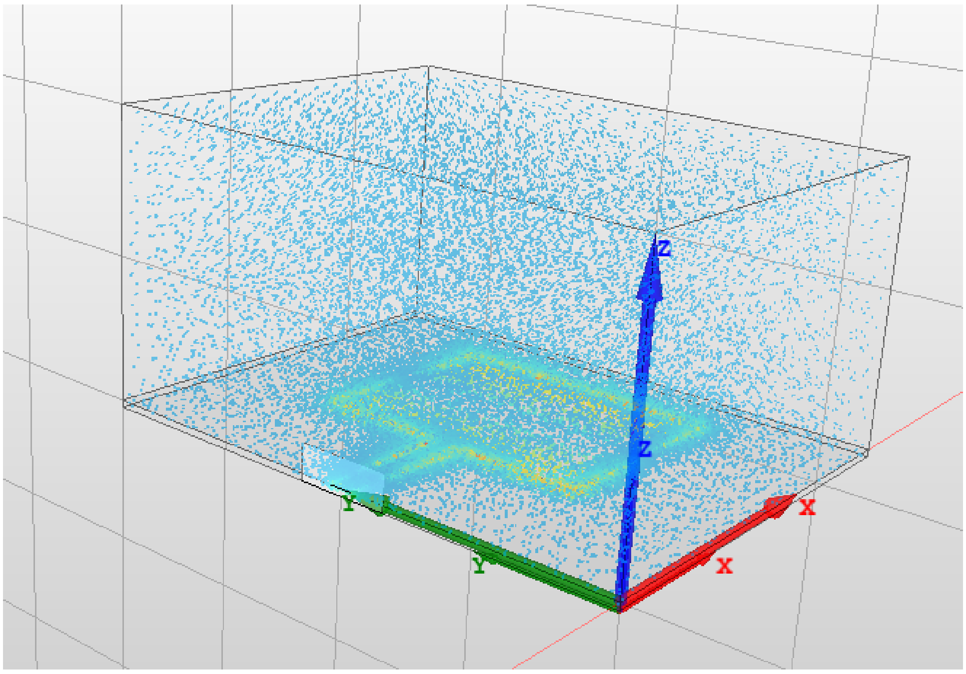

Figure 8: Cavity backed patch antenna, field pattern

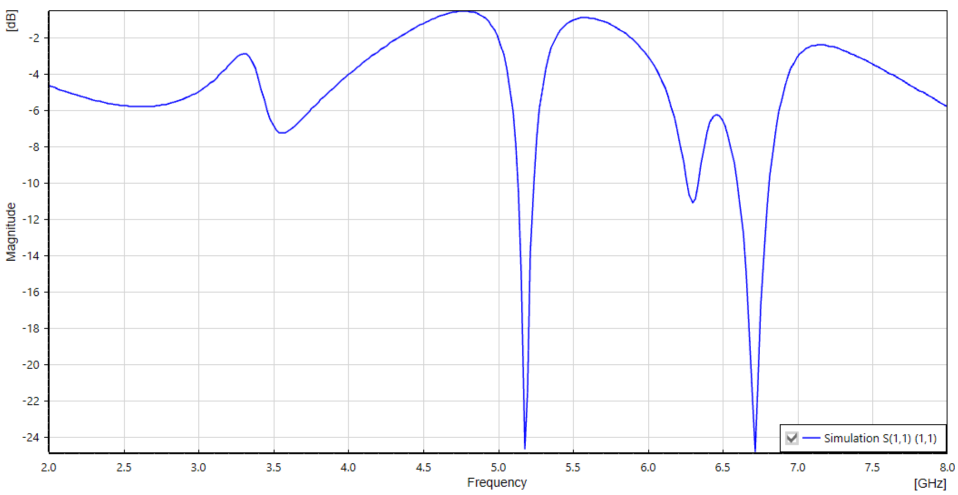

Figure 9: Cavity backed patch antenna, S-params, **LUMPED** excitation