

# A System-by-Design Approach for the Synthesis of WAIMs for Planar Arrays

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## Abstract

In this work, wide-angle impedance matching (*WAIM*) layers based on metasurfaces are designed to enhance the radiation efficiency of planar phased arrays. Toward this end, a System-by-Design (*SbD*) approach is adopted where the layer geometrical features are the solution descriptors, while the minimization of the array power reflection is the synthesis objective. Selected numerical examples are shown to illustrate the potentialities of the proposed *SbD*-based design strategy.

# 1 GUIDA D'ONDA CIRCOLARE - LATTICE QUADRATO (SbD approach)

Dielettrici considerati nelle analisi seguenti:

Dielettrico	$\varepsilon$	$\tan \delta$	$d$
tipo1=NY9208	2.08	0.0006	$0.508 \cdot 10^{-3}$
tipo2	2.08	0.6	$0.508 \cdot 10^{-3}$
tipo3	2.08	1	$0.508 \cdot 10^{-3}$
tipo4	2.08	1	$1.524 \cdot 10^{-3}$

Essendo  $\varepsilon$  la permittività elettrica,  $\tan \delta$  fattore di dissipazione e  $d$  lo spessore.

Per il materiale NY9208 è stato scelto di usare lo spessore più sottile tra quelli disponibili.

## 1.1 FORMA: Croce “2” (5 croci) - DIELETTRICO: TIPO 1 = NY9208

Il modello usato è una croce semplice della quale è possibile modificare lunghezza e larghezza delle braccia e angolo di tilt. Queste sono appunto le 3 incognite che andrà a modificare il PSO:

- *CrossLength*
- *CrossWidth*
- *TiltAngle*

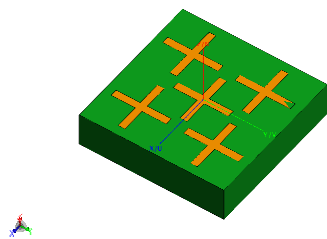


Figure 1: Croce, modello FEKO

Dielettrico:

- tipo: NY9208
- spessore:  $0.508e-3$
- $\varepsilon = 2.08$
- $\delta = 0.0006$
- $\rho = 1000.0 [kg/m^3]$

Parametri PSO:

- `swarm_size=10;`
- `max_iteration_number=100;`
- `ftol=0.0001;`
- `unknown_number=3`

Parametri da ottimizzare:

- $CrossLength = [0.0012 - 0.00135]$
- $CrossWidth = [0.00002 - 0.001]$
- $TiltAngle = [0^\circ - 3^\circ]$

- swarm\_filename=Initial.Swarm
- saving\_percentage=100;
- inertial\_weigth=0.4;
- inertial=2 (consider constant inertial velocity)
- choose\_parameter\_ab=1 (a≠b Random)
- $\alpha=\beta=0.4$
- $c1 = c2 = 2.0$

Fitness:

$$\Psi = \frac{1}{183} \cdot \sum_{\phi=0,45,90} \sum_{\theta=0}^{60} 1 - \Gamma^2$$

La Fitness è stata calcolata minimizzando il coefficiente di Riflessione sui 3 piani: E-plane ( $\phi = 0$ ), D-plane ( $\phi = 45$ ) e H-plane ( $\phi = 90$ ) considerando l'angolo  $\theta$  da 0 a  $60^\circ$

- $\theta = [0 : 60]$
- $\phi = [0; 45; 90]$

$$\Psi_{min} = 4.14 \cdot 10^{-2}$$

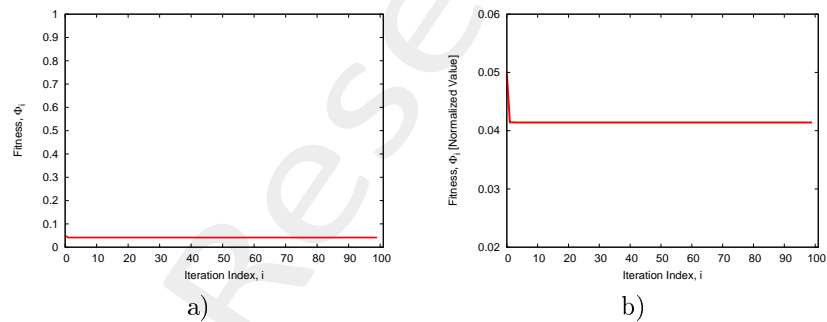


Figure 2: a) Fitness , b) zoom

Il risultato ottimo si ottiene all'iterazione 4 particella 2:

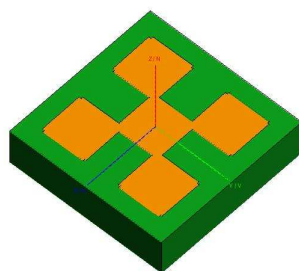


Figure 3: Unit cell, modello FEKO, figura ottima

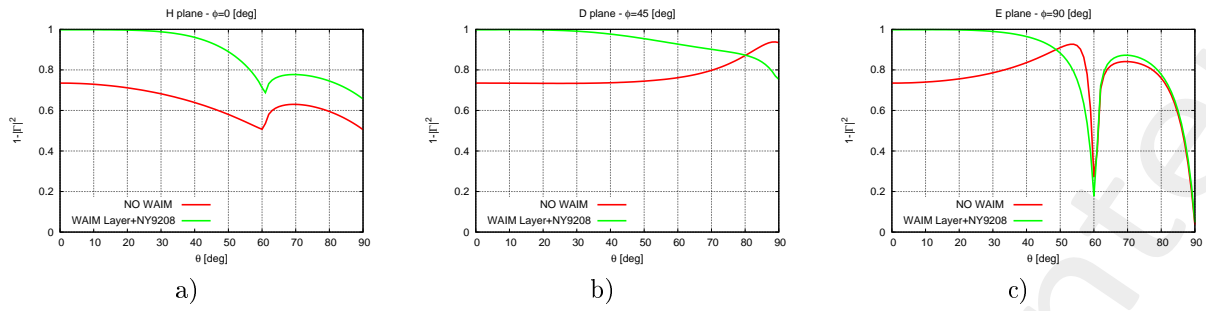


Figure 4: Coefficiente di Trasmissione, a) Piano H, b) Piano D, c) Piano E

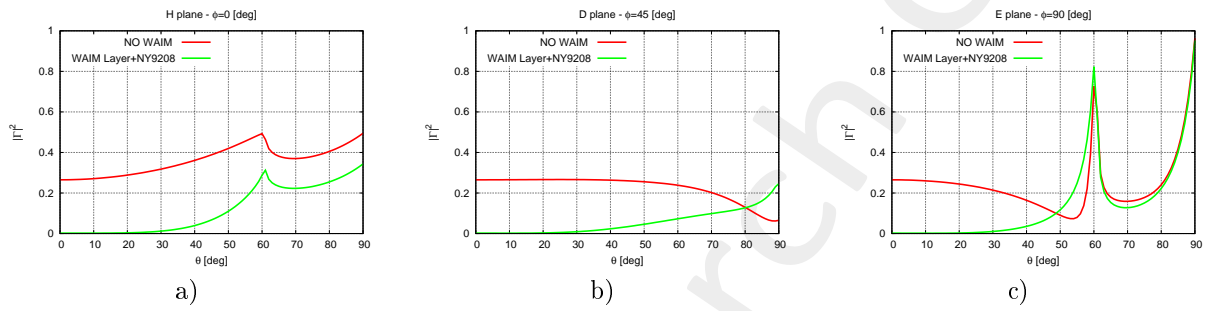


Figure 5: Coefficiente di Riflessione, a) Piano H, b) Piano D, c) Piano E

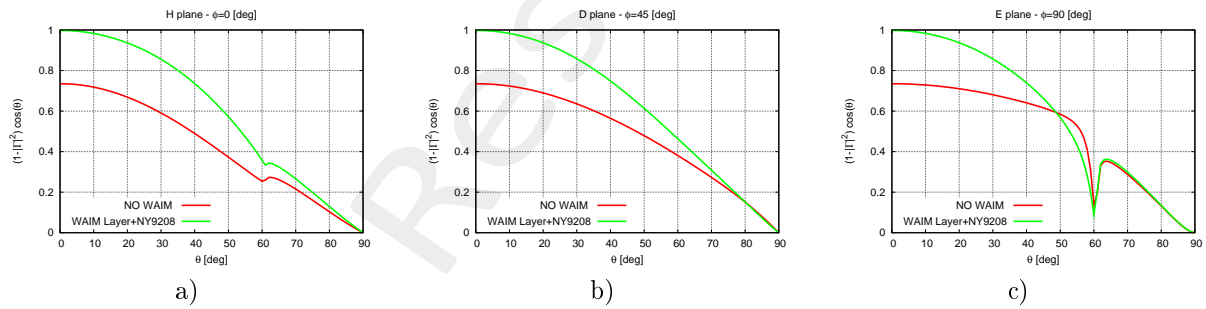


Figure 6: Coefficiente di Trasmissione  $\cdot \cos(\theta)$ , a) Piano H, b) Piano D, c) Piano E

## 1.2 FORMA: Croce “2” (5 croci) - DIELETTRICO: TIPO 2

Dielettrico:

- tipo: 2
- spessore:  $0.508e-3$
- $\varepsilon = 2.08$
- $\delta = 0.6$
- $\rho = 1000.0 [kg/m^3]$

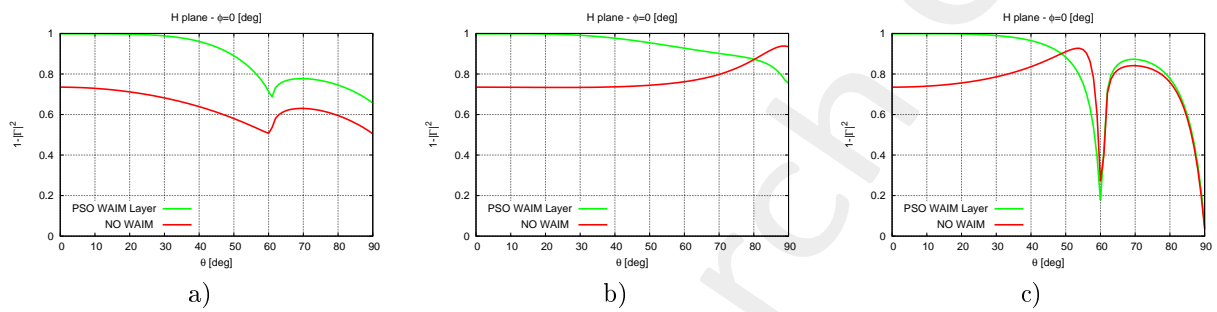


Figure 7: Coefficiente di Trasmissione, a) Piano H, b) Piano D, c) Piano E

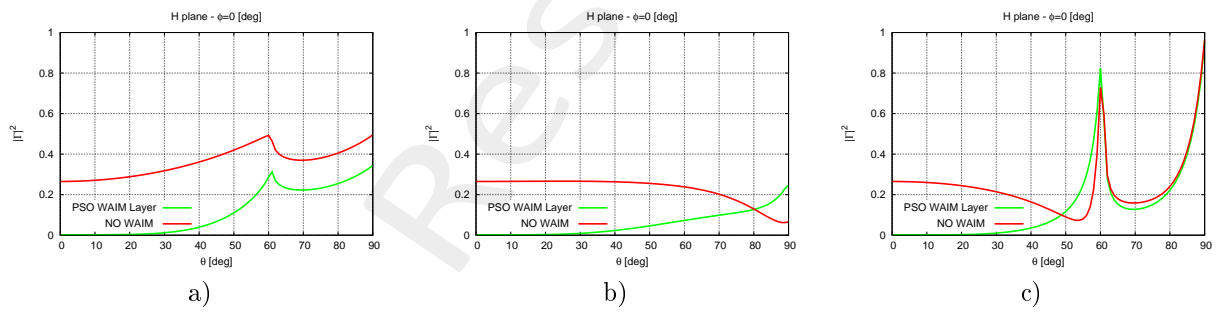


Figure 8: Coefficiente di Riflessione, a) Piano H, b) Piano D, c) Piano E

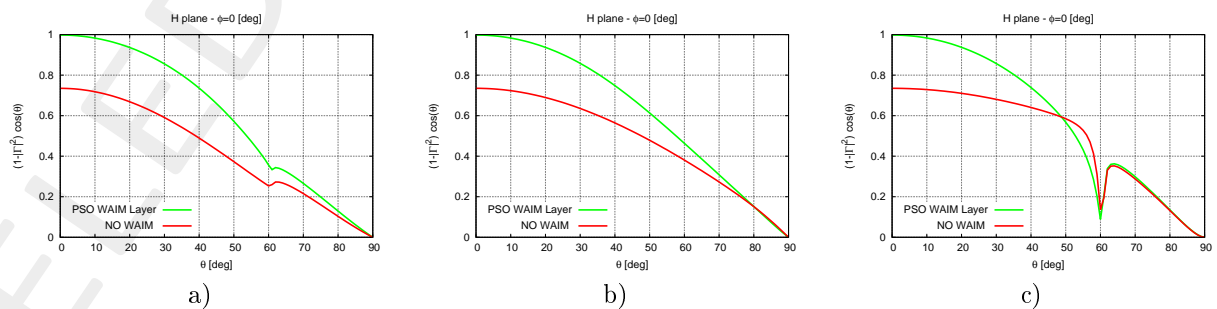


Figure 9: Coefficiente di Trasmissione  $\cdot \cos(\theta)$ , a) Piano H, b) Piano D, c) Piano E

### 1.3 FORMA: Croce “2” (5 croci) - DIELETTRICO: TIPO 3

Dielettrico:

- tipo: 3
- spessore:  $0.508e-3$
- $\varepsilon = 2.08$
- $\delta = 1$
- $\rho = 1000.0 [kg/m^3]$

Di seguito alcune figure dei coefficienti di trasmissione e riflessione all'iterazione 8 particella 4:

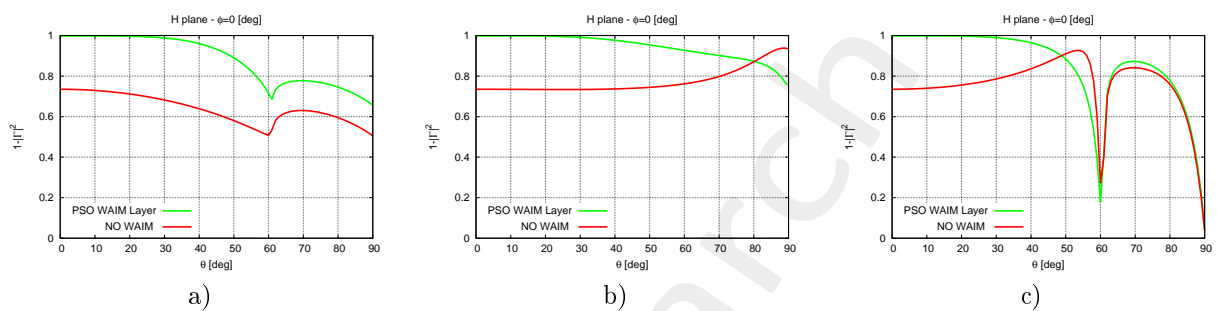


Figure 10: Coefficiente di Trasmissione, a) Piano H, b) Piano D, c) Piano E

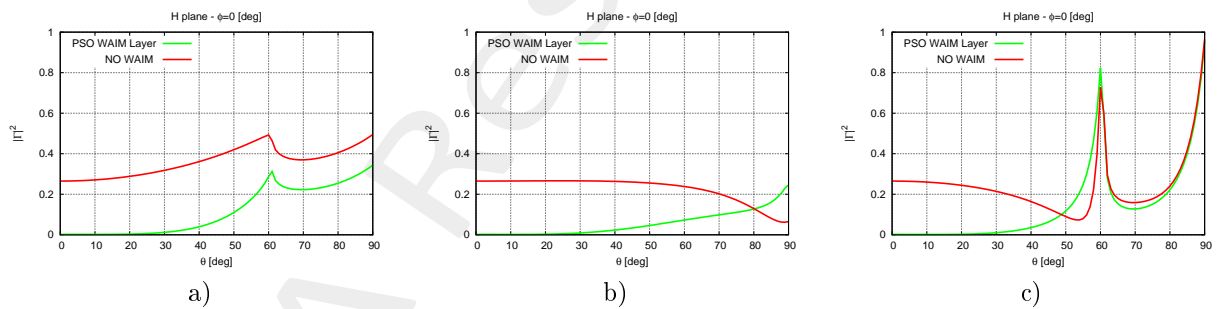


Figure 11: Coefficiente di Riflessione, a) Piano H, b) Piano D, c) Piano E

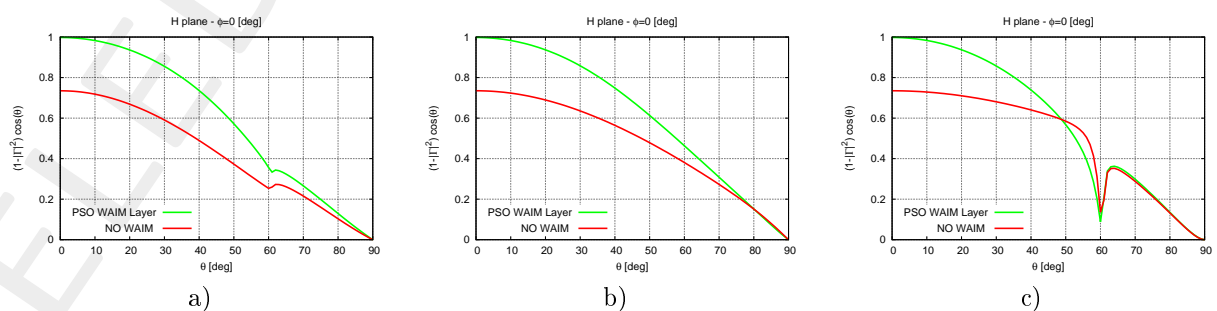


Figure 12: Coefficiente di Trasmissione  $\cdot \cos(\theta)$ , a) Piano H, b) Piano D, c) Piano E

## 1.4 FORMA: Croce “2” (5 croci) - DIELETTRICO: TIPO 4

Dielettrico:

- tipo: 4
- spessore:  $1.524e-3$
- $\varepsilon = 2.08$
- $\delta = 1$
- $\rho = 1000.0 [kg/m^3]$

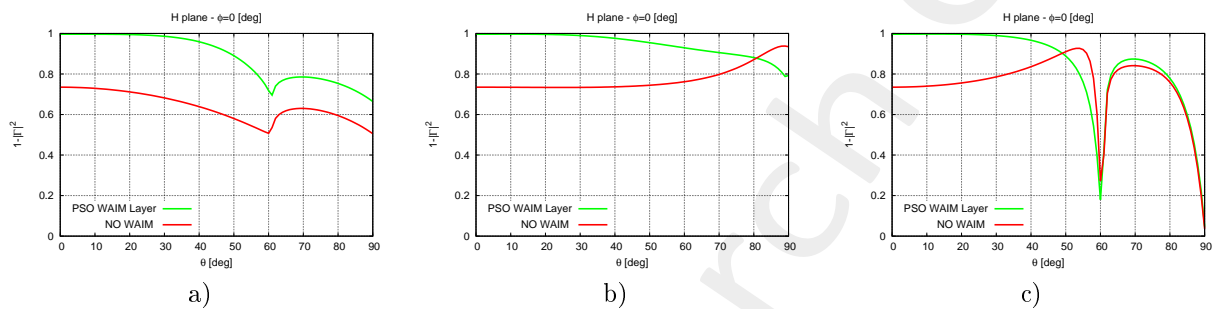


Figure 13: Coefficiente di Trasmissione, a) Piano H, b) Piano D, c) Piano E

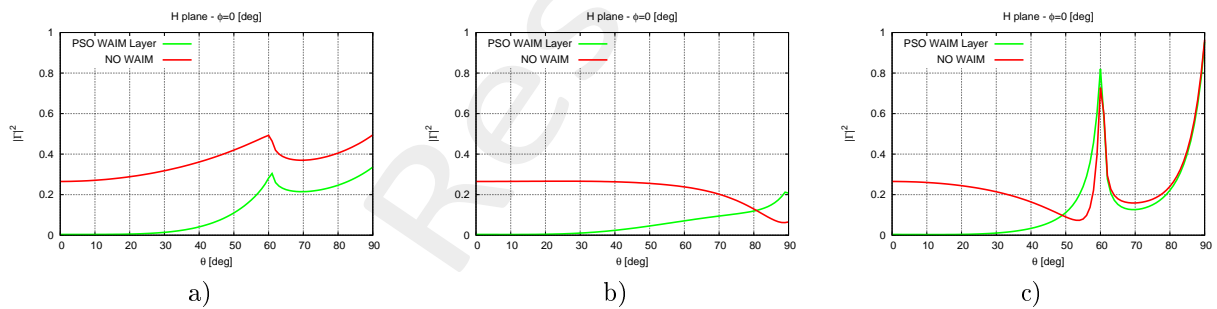


Figure 14: Coefficiente di Riflessione, a) Piano H, b) Piano D, c) Piano E

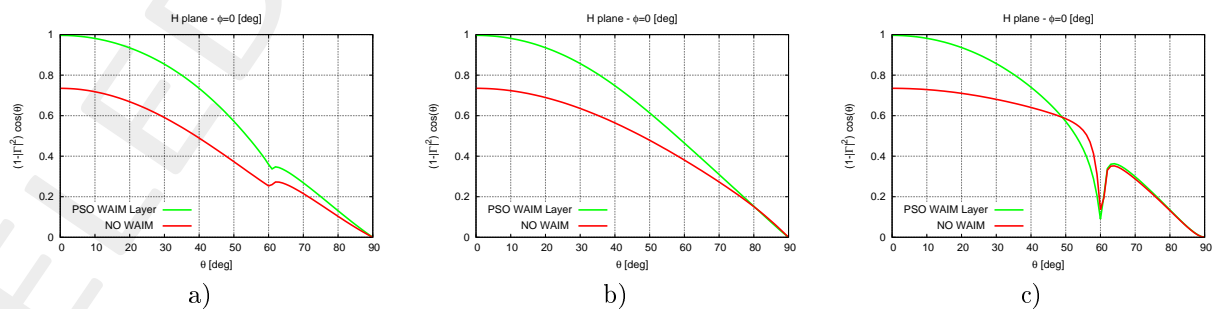


Figure 15: Coefficiente di Trasmissione  $\cdot \cos(\theta)$ , a) Piano H, b) Piano D, c) Piano E



## 1.5 Unit cell shape

Nei 3 casi si ottengono celle elementari leggermente diverse, anche se da figura non è molto visibile.

	Dielettrico			
	Tipo 1	Tipo 2	Tipo 3	Tipo 4
CrossLength	1.20000006E-03	1.30000000E-03	1.20000006E-03	1.30000000E-03
CrossWidth	5.50224213E-04	6.77957491E-04	7.01327110E-04	1.00000005E-03
TiltAngle	1.13998795E+00	1.19258332E+00	0.00000000E+00	1.90000005E-01

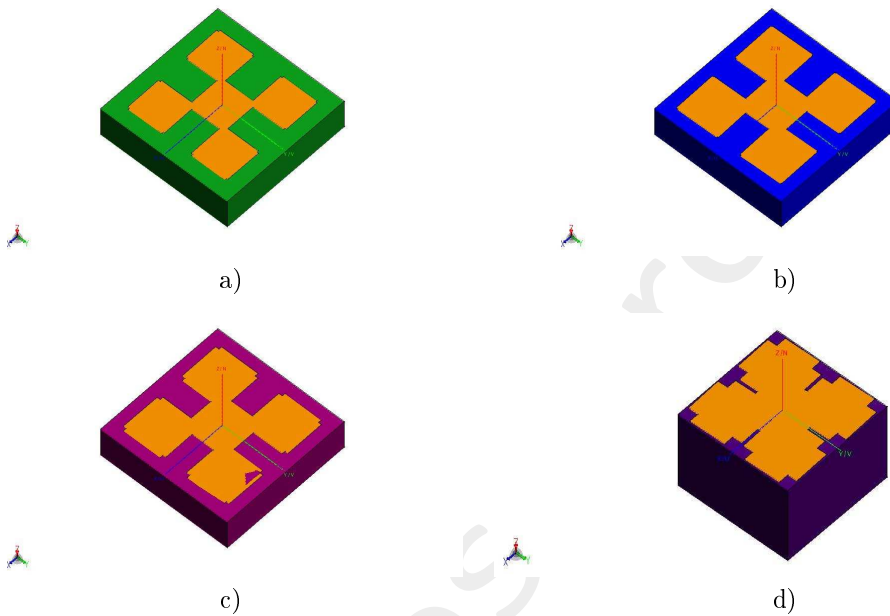


Table 1: Optimal Unit cells, a) using NY9208, b) lossy dielectric type2, c) lossy dielectric type3 , d)lossy dielectric type4

## References

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