WAIM-Based Dual-Polarized Antenna Synthesis for 5G Base Station

G. Oliveri, M. Salucci and A. Massa

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1.1.1 PSO [$Q = 8$, $K = 9$, $P = 8$, $I = 50$]

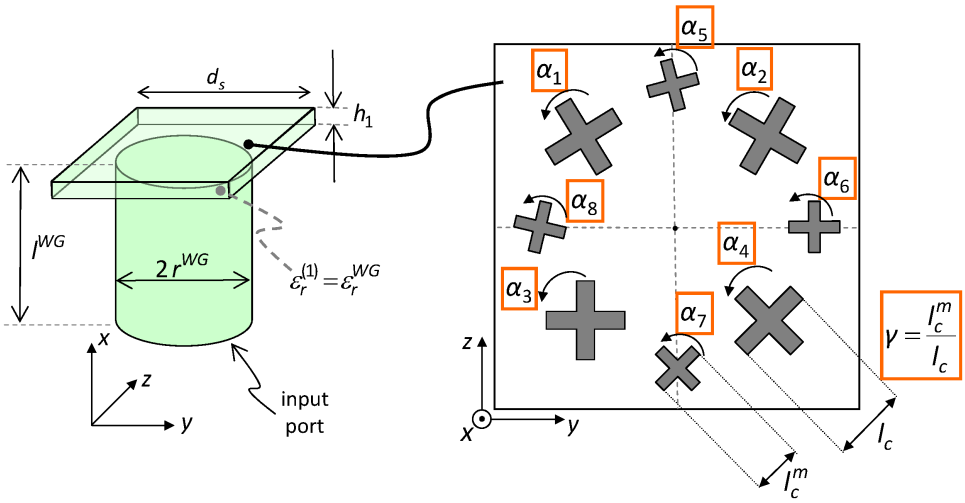
Find a configuration of the WAIM able to minimize the scan loss with eight symmetrical crosses as metallizations. Some of the parameters such as l_c, w_c, d_c, h_1 are preserved from the best solution with $Q = 4$ (III). The DoFs are the angles of the added four crosses which are free and the scaling with respect to the previous crosses. These should enable higher performance and the symmetry should again preserve the array behaviour in steering and between the modes/polarizations

DoFs

- Number of variables, $K = 9$
- Number of WAIM crosses, $Q = 8$
- Optimization variables and ranges

Physical Meaning	Variable	min	max
Tilt of upper left cross	α_1	0 [deg]	90 [deg]
Tilt of upper right cross	α_2	0 [deg]	90 [deg]
Tilt of lower left cross	α_3	0 [deg]	90 [deg]
Tilt of lower right cross	α_4	0 [deg]	90 [deg]
Tilt of secondary upper cross	α_5	0 [deg]	90 [deg]
Tilt of secondary left cross	α_6	0 [deg]	90 [deg]
Tilt of secondary right cross	α_7	0 [deg]	90 [deg]
Tilt of secondary lower cross	α_8	0 [deg]	90 [deg]
Scaling	γ	20 [%]	75 [%]

Table I: Variable ranges ($Q = 8$, $K = 9$) - Minimum and maximum allowed values.



(a)

Figure 1: WAIM ($Q = 8$) - Variable physical meaning on the WAIM geometry.

Optimization Parameters

- Optimization algorithm, *PSO*
- Number of particles, $P = 8$
- Number of iterations, $I = 50$
- Swarm initialization, *Random*
- Inertial weight, $w = 0.8$
- Acceleration coefficients, $C_1 = C_2 = 2.0$
- Random seed value, $s = 1$

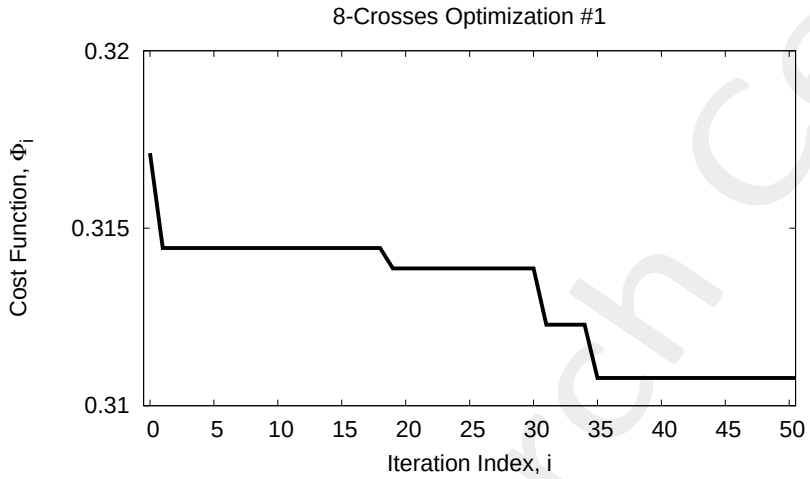
Cost Function

- Angles considered, $N_a = 9$
  - $\phi \in \{-60,\, 0,\, 60\}\,[\text{deg}] \times \theta \in \{75,\, 90,\, 105\}\,[\text{deg}]$
- Frequencies considered, $N_f = 3$

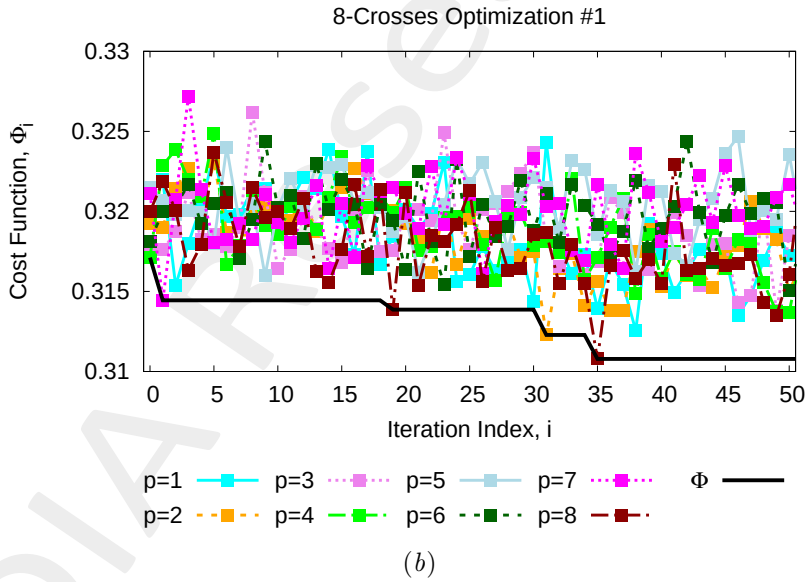
– $f = \{3.30, 3.55, 3.80\}$ [GHz]

- Modes considered, $N_m = 2$ (± 45 [deg])
- S-parameter threshold, $S_{th} = -10$ [dB]

Results



(a)



(b)

Figure 2: *Periodic model* ($Q = 8$, $s = 1$, $P = 8$, $I = 50$) - *PSO* Optimization. Cost vs iteration for (a) the global best solution of the *PSO* and (b) showing also the cost of all the *PSO* particles ($p = 1, \ldots, 8$).

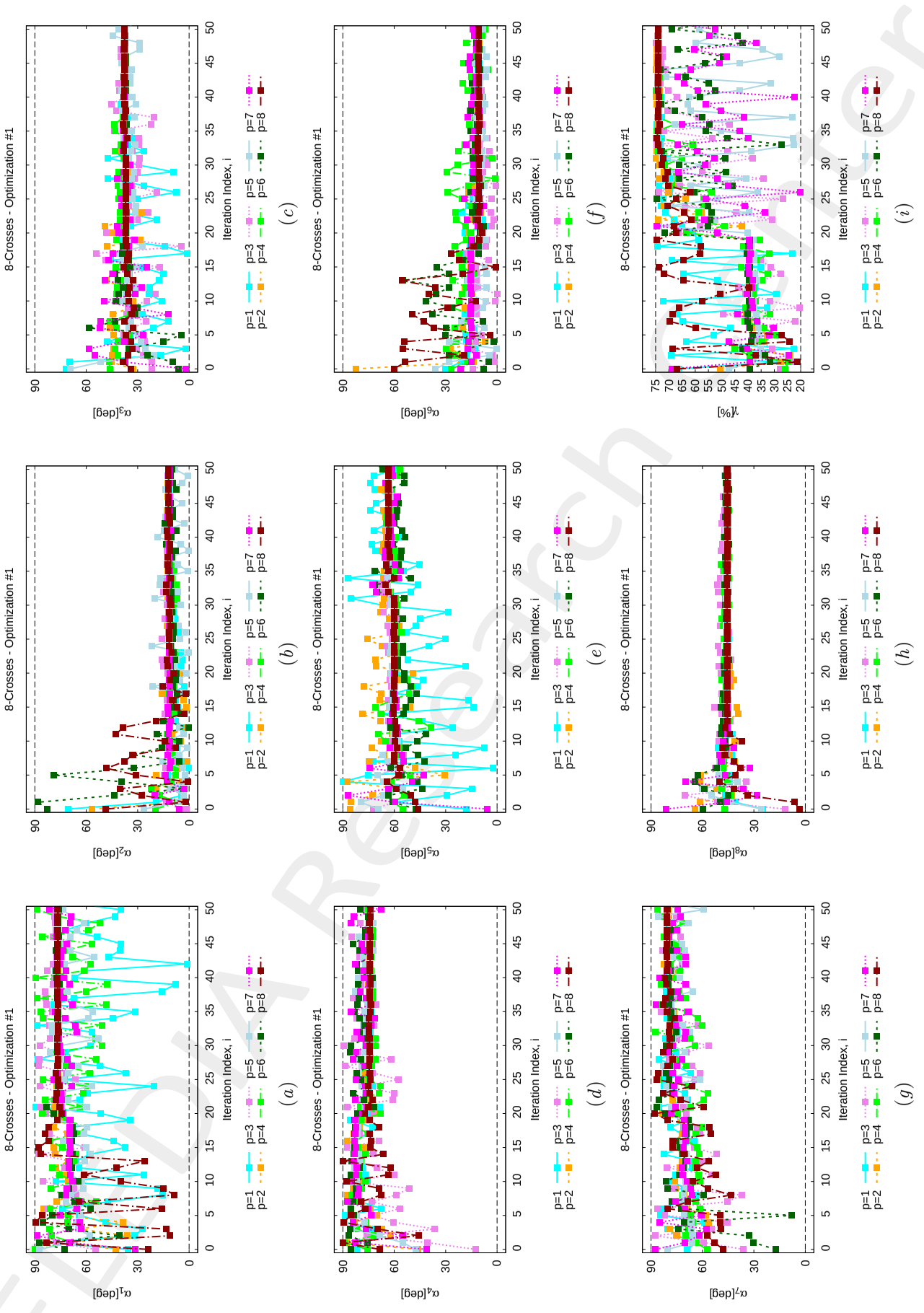


Figure 3: *Periodic model* ($Q = 8$, $s = 1$, $P = 8$, $I = 50$) - *PSO* Optimization. Variable vs iteration for all the *PSO* particles ($p = 1, \ldots, 8$).

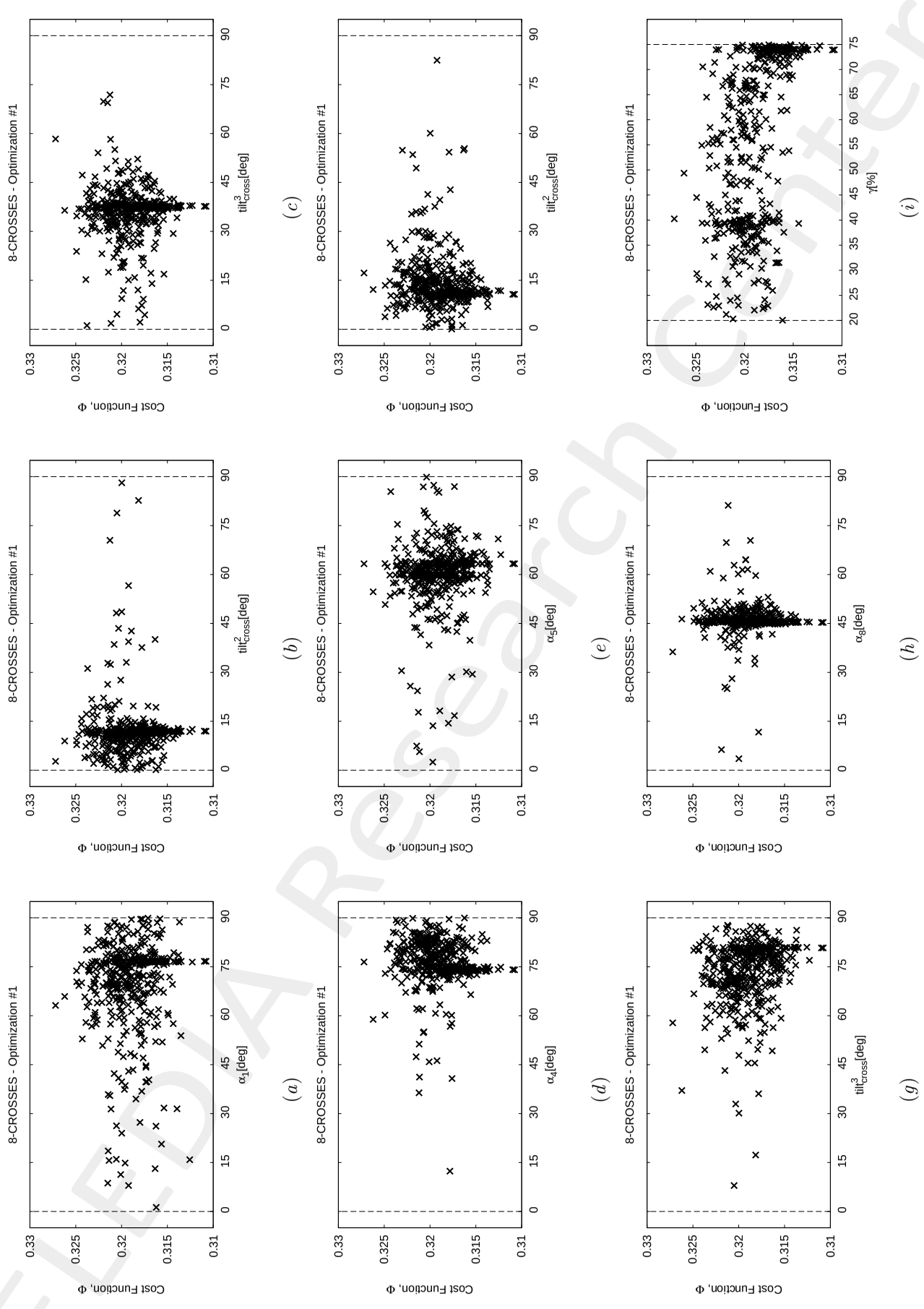


Figure 4: *Periodic model* ($Q = 8$, $s = 1$, $P = 8$, $I = 50$) - *PSO* Optimization. Cost vs variable for all the configurations simulated during the optimization.

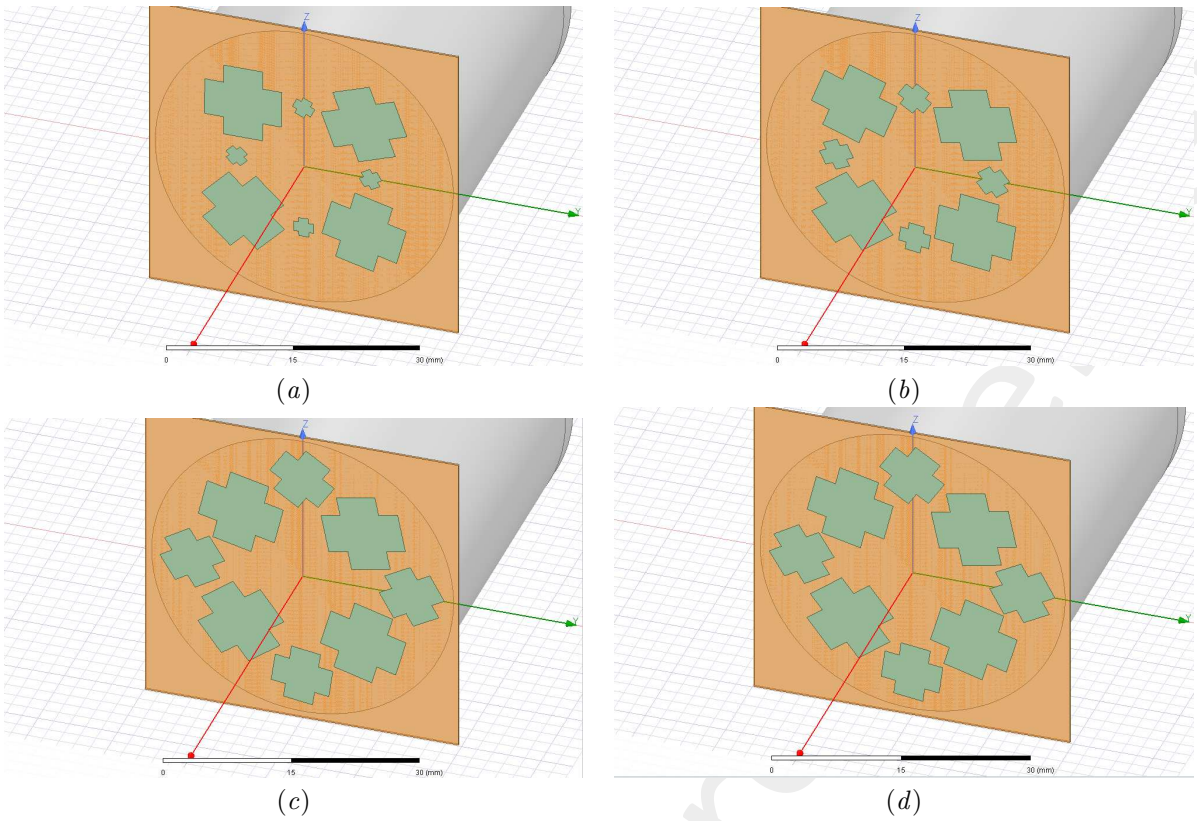


Figure 5: *Periodic model* ($Q = 8$, $s = 1$, $P = 8$, $I = 50$) - *PSO* Optimization. Best solution geometry at iterations (a) $i = 0$, (b) $i = 10$, (c) $i = 20$, (d) $i = 40$.

Iteration, i	Φ
0	3.171×10^{-1}
10	3.144×10^{-1}
20	3.139×10^{-1}
30	3.139×10^{-1}
40	3.108×10^{-1}
50	3.108×10^{-1}

Table II: *Periodic model* ($Q = 8$, $s = 1$, $P = 8$, $I = 50$) - *PSO* Optimization. Cost function at the first iteration compared with the latest iteration. The first iterations represents a random sampling with $P = 8$ samples.

Physical Meaning	Variable	Value	$Q = 4$ $s = 1$(Tab. III)
Length of the cross arms	l_c	9.836 [mm]	9.836 [mm]
Width of the cross arms	w_c	4.953 [mm]	4.953 [mm]
Distance of the cross centers from the FWG center	d_c	7.706 [mm]	7.706 [mm]
Superstrate thickness	h_1	0.245 [mm]	0.245 [mm]
Tilt of upper left cross	α_1	76.68 [deg]	12.70 [deg]
Tilt of upper right cross	α_2	11.96 [deg]	28.00 [deg]
Tilt of lower left cross	α_3	37.68 [deg]	27.65 [deg]
Tilt of lower right cross	α_4	74.07 [deg]	19.50 [deg]
Tilt of secondary upper cross	α_5	63.31 [deg]	/
Tilt of secondary left cross	α_6	10.70 [deg]	/
Tilt of secondary right cross	α_7	80.80 [deg]	/
Tilt of secondary lower cross	α_8	45.30 [deg]	/
Scaling	γ	73.9 [%]	/

Table III: *Periodic model* ($Q = 8$, $s = 1$, $P = 8$, $I = 50$) - *PSO* Optimization. Parameter values of the best solution.

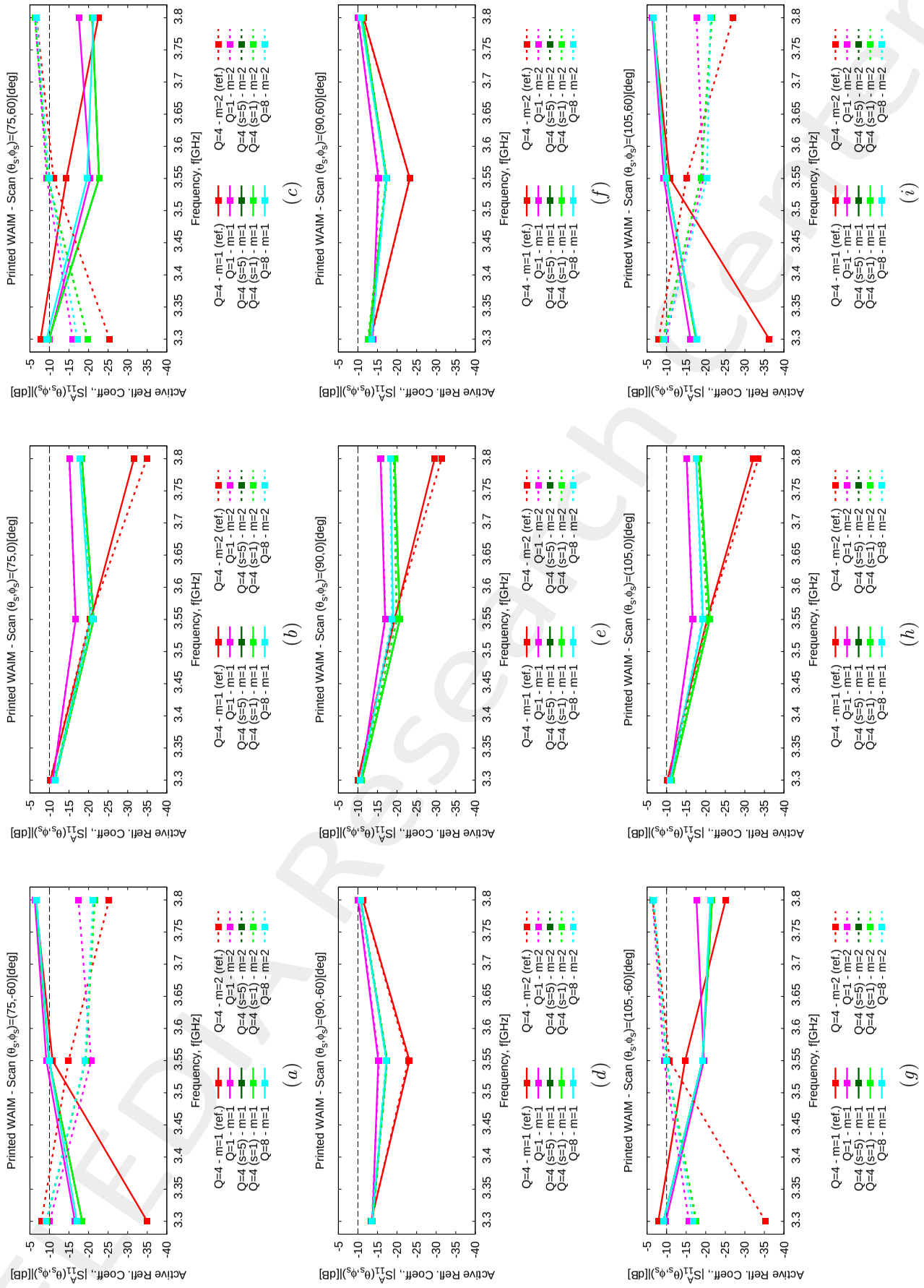


Figure 6: *Periodic model* ($Q = 8$, $s = 1$, $P = 8$, $I = 50$) - S-parameter performance of best solution obtained with each $Q = 8$ compared with the previous setups ($Q = 1$, $Q = 4$), reported in the frequency range for the two polarizations ($m = 1, 2$) and in all the considered array scan points. The "*Reference*" solution, in red, comes from a previous optimization $Q = 4$ where the frequency range was $f \in [3.4, 3.8]$ [GHz]

Observations

- The dynamic of the cost function curve is very limited, probably due to the fixing of several parameters related to the four "base" crosses from a previous optimization.
- After just $i \simeq 10$ iterations the performance are better than the $Q = 4$ best solution.
- Overall the final solution improves only of 1.3% with respect to the best solution with $Q = 4$ crosses which is an almost negligile improvement as can be seen in Fig. 6.

More information on the topics of this document can be found in the following list of references.

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