An Innovative Approach for the Design of Thinned 2D Arrays Based on Evolutionary Optimization and Almost Difference Sets

M. Salucci, G. Gottardi, N. Anselmi, and G. Oliveri

Abstract

In this work, a novel approach for the design of 2D thinned phased arrays is proposed. The developed strategy is able to exploit the efficiency of analytical almost difference sets (*ADS*s) and the effectiveness of evolutionary optimization in exploring the search space of all possible solutions. Towards this end, a binary optimization technique inspired by the genetic algorithm (*GA*) is properly customized by adapting its basic operators in order to exploit the *a-priori* information provided by the *ADS* sequences. Some numerical results are shown in order to assess the proposed ADSGA technique for thinning planar arrays, as well as to directly compare it to state-of-the-art solutions.

1 Problem II-b - PSL Minimization in Array Synthesis (Comparison ADSGA vs. Haupt [1])

In order to determine an optimal thinned configuration starting from the (usually) sub-optimal ADS arrangement with a given aperture size N_{ADS} and thinning factor ν_{ADS}, let us formulate the following constrained optimization problem

$$Min\left(F\{\rho\}\right) = \frac{max_{(u,v)\notin R_m^2}\left\{\left|S(u,v)\right|^2\right\}}{\left|S(0,0)\right|^2}$$

subject to $K \neq K_{ADS}$ ($K > K_{ADS}$) and $N_x \neq N_{x-ADS}$ and $N_y \neq N_{y-ADS}$ ($N > N_{x-ADS}$ and $N_y > N_{y-ADS}$) to be solved through ADSGA.

In such a case, the GA fitness function is defined as the PSL of the array while the constraints force the array to kept its descriptive parameters.

- PSL: Kopilovich
- Initialization: Random vs Hybrid
- Fitness: PSL and Thinning: Per poter confrontare i risultati con Haupt [1], la funzione di fitness è stata definita come

$$\Psi(i) = \frac{\alpha}{PSL^i_{\phi=0} + PSL^i_{\phi=90}} + \beta\nu^i$$

where i is associated to the i-th trial solution.

COMPARISON ADSGA VS HAUPT [1]

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Vedere [1] per maggiori dettagli.

RESULTS: $P = 10$, $Q = 20$

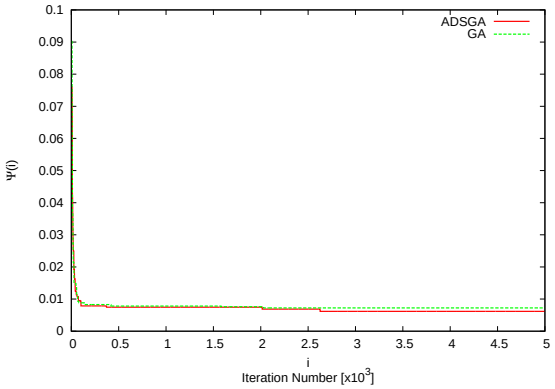
Setting Parameters of Algorithms

GA Parameters

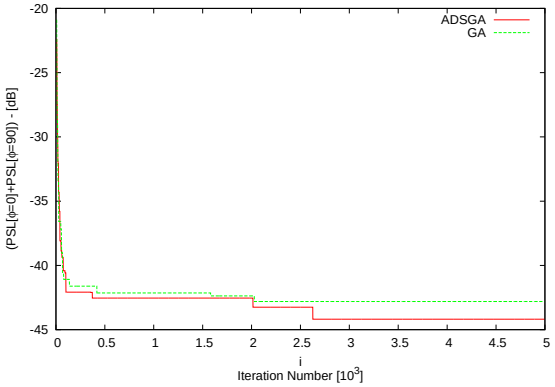
- Chromosome Dimension $C = 200\, bits$
- Population Dimension $S = 60$
- Max Iteration number $K_{max} = 5000$

FFT Parameters

- $FFT\ Theta = 256$
- $FFT\ Phi = 256$



(a)



(b)

Figure 1.

Figure 1:

- (a) :$\Psi(i)$
- (b) :$PSL[\phi = 0] + PSL[\phi = 90]$

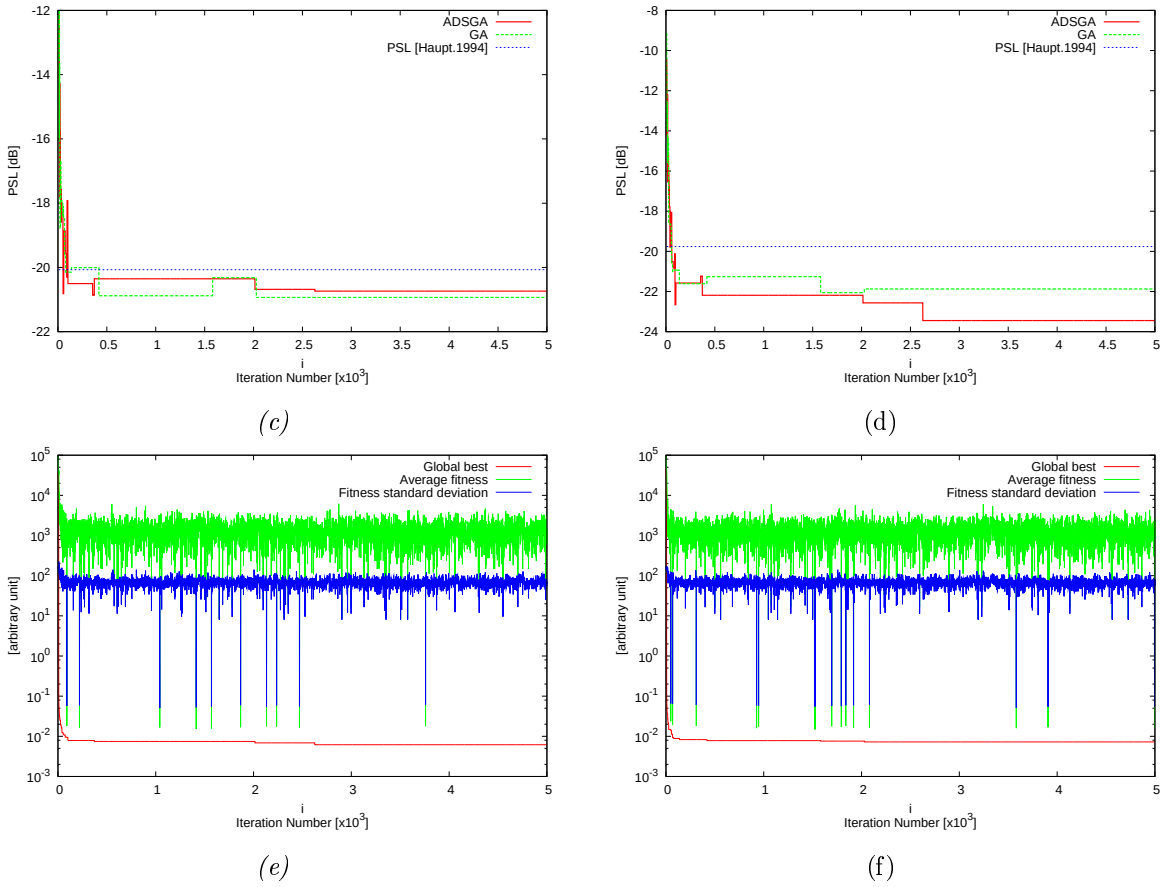


Figure 2.

Figure 2:

- $\phi = 0$ (c), $\phi = 90(d)$
- ADSGA approach (e), GA approach (f)

Array Parameters Starting Geometry

- Number of total cells $N = 77$
- Dimension X: 7
- Dimension Y: 11

Array Parameters Final Geometry

- Number of total cells $N = 200$
- Dimension X: 10
- Dimension Y: 20

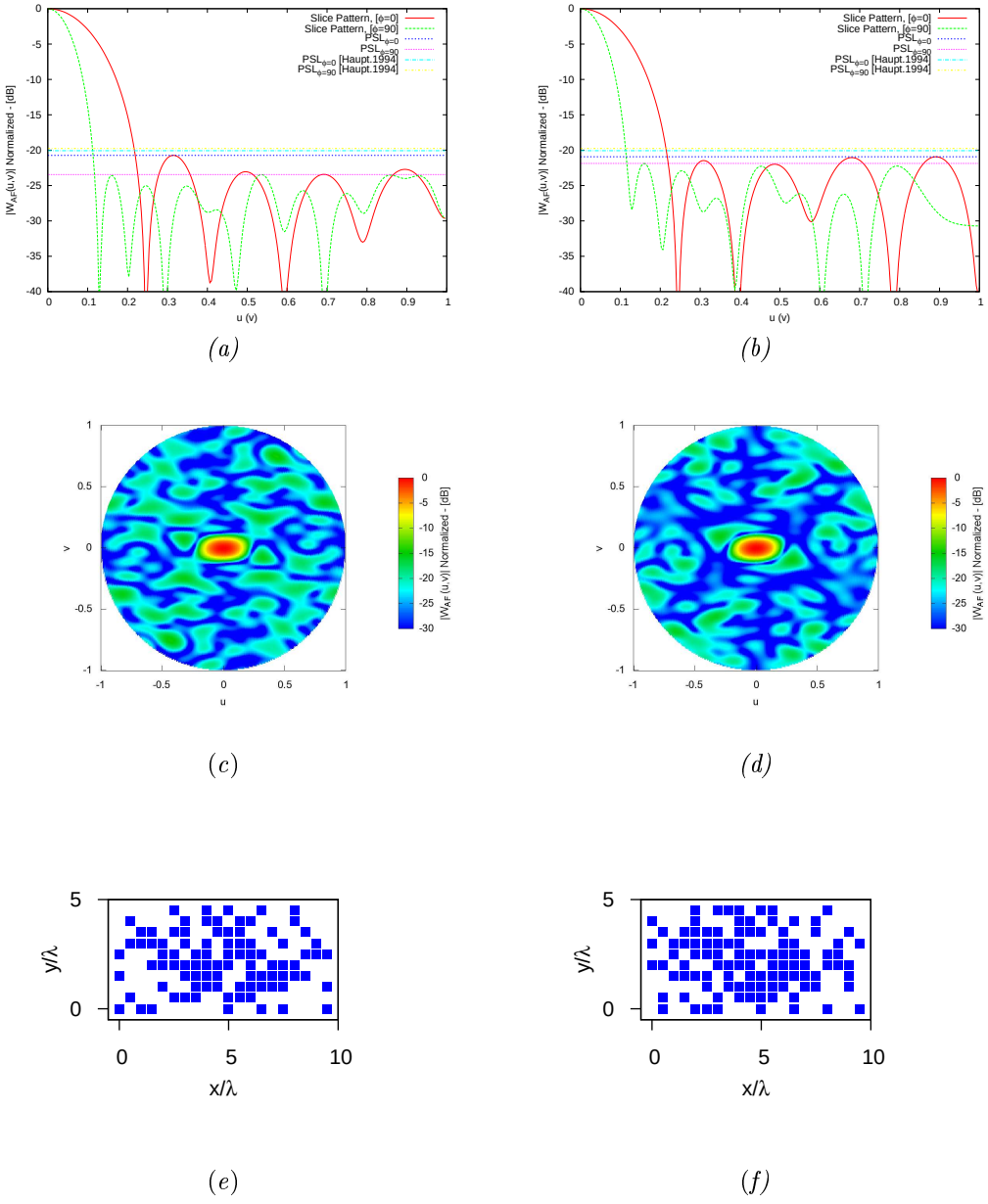


Figure 3.

Figure 3:

- ADSGA approach (a, c, e), GA approach (b, d, f)

RESULTS: $P = 40$, $Q = 40$

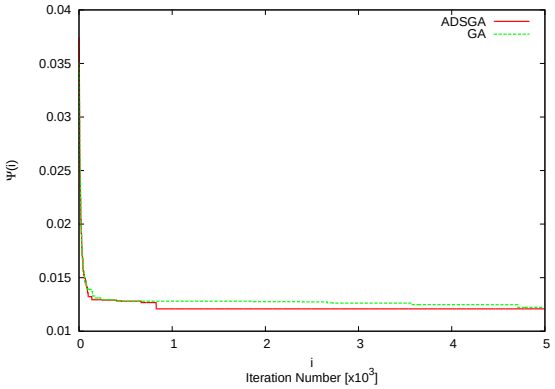
Setting Parameters of Algorithms

GA Parameters

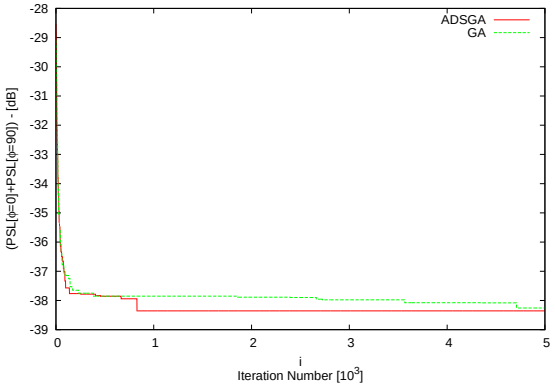
- Chromosome Dimension $C = 1600\, bits$
- Population Dimension $S = 200$
- Max Iteration number $K_{max} = 5000$

FFT Parameters

- $FFT\ Theta = 512$
- $FFT\ Phi = 512$



(a)



(b)

Figure 4.

Figure 4:

- (a) :$\Psi(i)$
- (b) :$PSL[\phi = 0] + PSL[\phi = 90]$

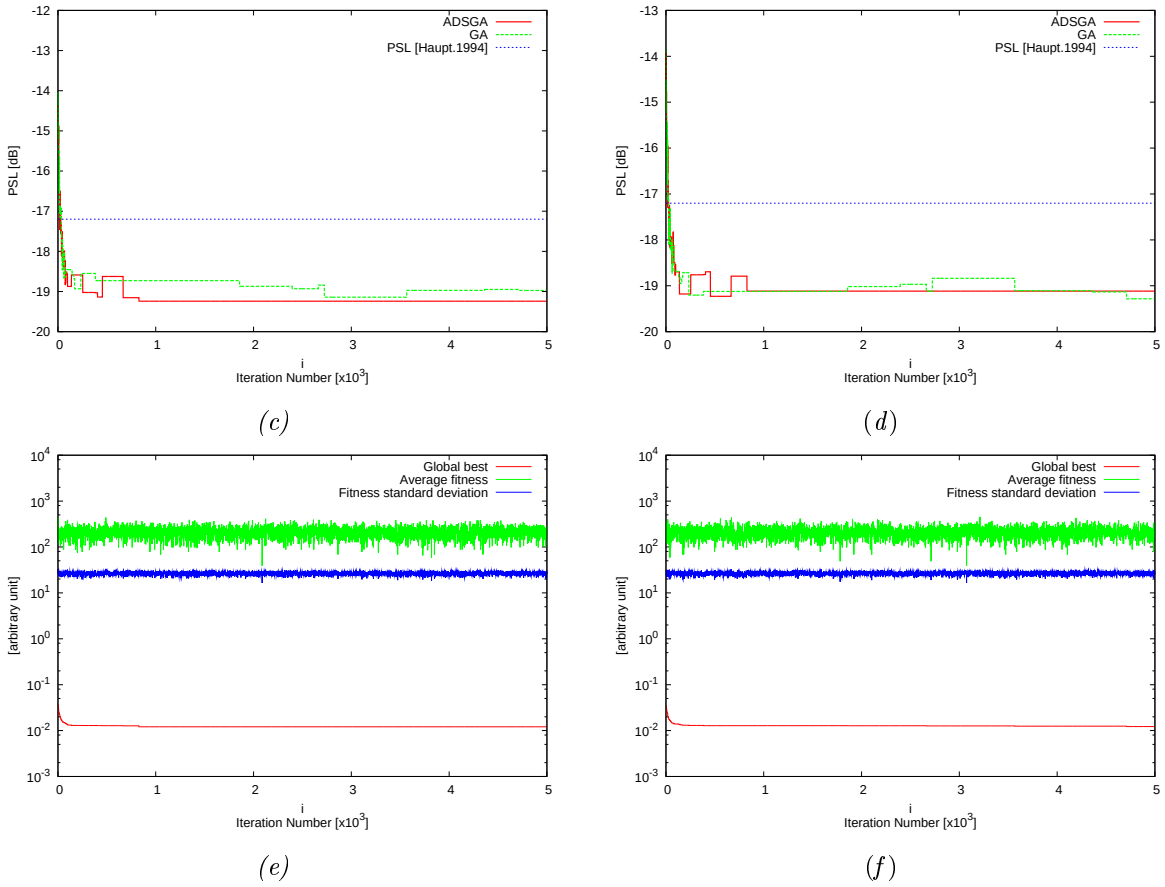


Figure 5.

Figure 5:

- $\phi = 0$ (c), $\phi = 90(d)$
- ADSGA approach (e), GA approach (f)

Array Parameters Starting Geometry

- Number of total cells $N = 1369$
- Dimension X: 37
- Dimension Y: 37

Array Parameters Final Geometry

- Number of total cells $N = 1600$
- Dimension X: 40
- Dimension Y: 40

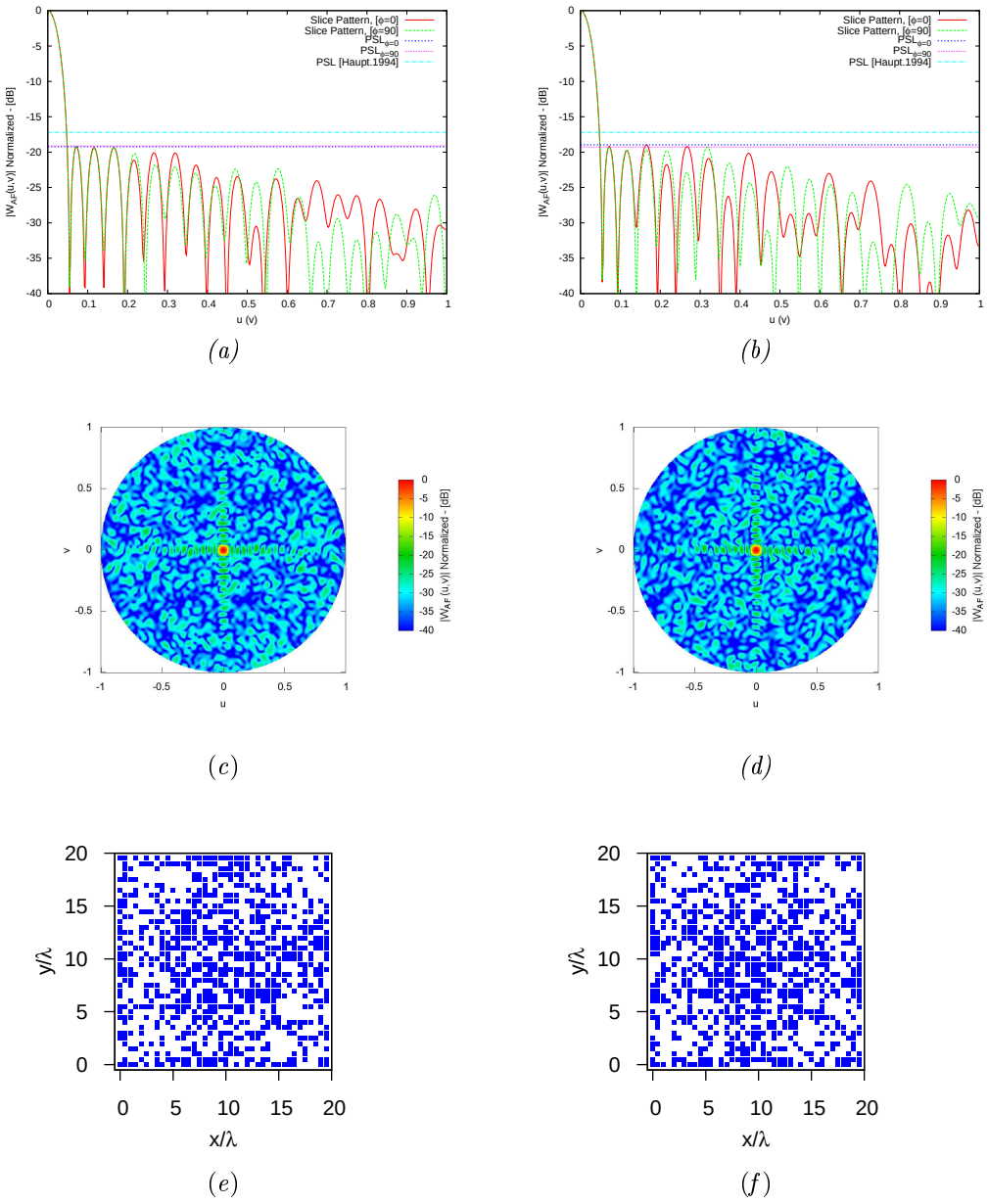


Figure 6.

Figure 6:

- ADSGA approach (a, c, e), GA approach (b, d, f)

		$ADSGA$	GA	$GA-[Haupt]$ [1]
PXQ		$\nu[\%]$	$\nu[\%]$	$\nu[\%]$
$10X20$		0.455	0.515	0.54
$40X40$		0.485	0.491	0.81

Table I.a

	$GA-[Haupt.1994]$		$ADSGA$		GA	
PXQ	$BW\ \phi=0$	$BW\ \phi=90$	$BW\ \phi=0$	$BW\ \phi=90$	$BW\ \phi=0$	$BW\ \phi=90$
$10X20$	0.2480	0.1289	0.2412	0.1289	0.2460	0.1289
$40X40$	0.0546	0.0546	0.0546	0.0546	0.0546	0.0546

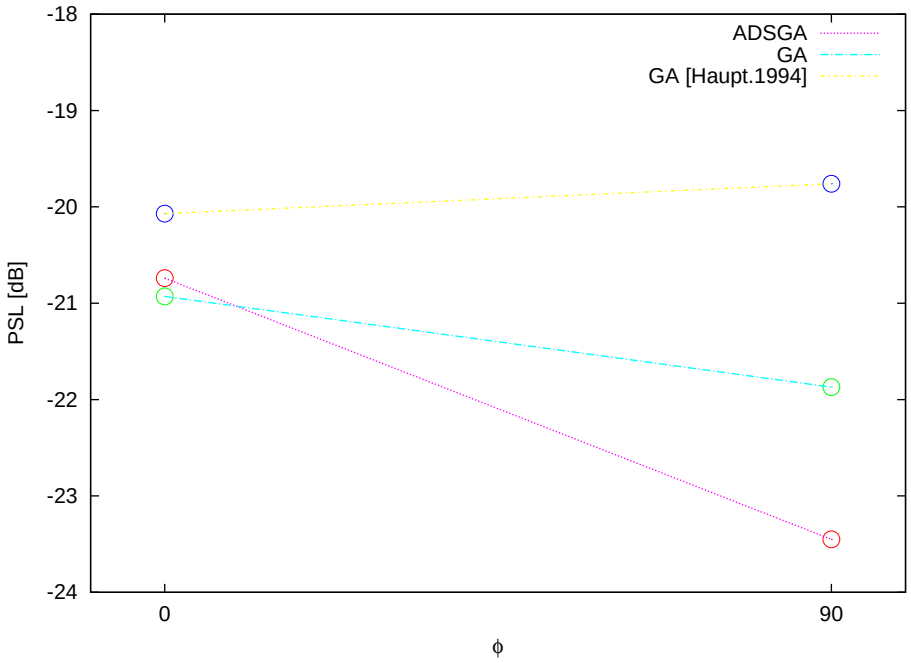
Table I.b

	$ADSGA$	GA	$GA-[Haupt.1994]$
PXQ	$PSL_{\phi=0}[dB]$	$PSL_{\phi=0}[dB]$	$PSL_{\phi=0}[dB]$
$10X20$	-20.74	-20.93	-20.07
$40X40$	-19.24	-18.97	-17.20

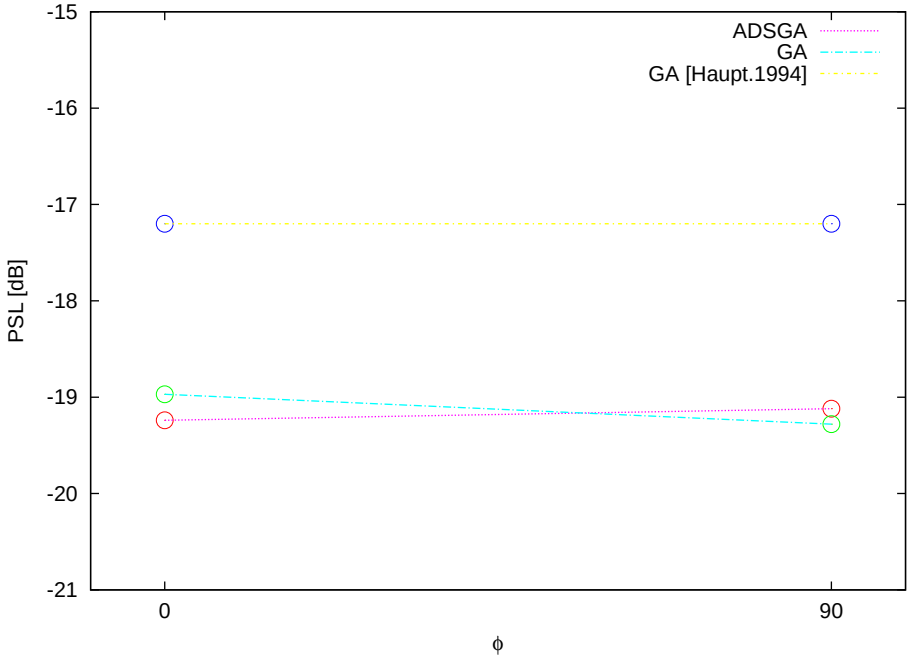
Table II.a

	$ADSGA$	GA	$GA-[Haupt.1994]$
PXQ	$PSL_{\phi=90}[dB]$	$PSL_{\phi=90}[dB]$	$PSL_{\phi=90}[dB]$
$10X20$	-23.45	-21.87	-19.76
$40X40$	-19.12	-19.28	-17.20

Table II.b



(a)



(b)

Figure 7.

NOTA **Figure 7:**

- Array $P = 10$, $Q = 20$, Figure 40-(a)
- Array $P = 40$, $Q = 40$, Figure 40-(b)

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