ADS-Guided Design of Planar Thinned Phased Arrays Through Genetic Optimization

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Abstract

This work presents an innovative hybrid approach for synthesizing thinned planar phased arrays. The *a-priori* information provided by analytical almost difference sets (*ADS*s) is profitably exploited by a customized stochastic optimization approach based on genetic algorithms (*GA*s). Such an *ADSGA* approach is able to overcome the current limitations of state-of-the-art techniques based on *ADS*s. Some numerical results are shown in order to assess the potentialities, as well as the limitations, of the proposed design methodology.

1 Problem III - Definition of a General Purpose ADS Construction technique for Array Synthesis

With reference to the potential limitation outlined in the Introduction, the aim is now to and the explicit forms of ADS s sequences (i.e., binary sequences with a three-level auto-correlation function) for arbitrary values of N . Towards this end, let us denote with $L\{\rho\}$ and $R\{\rho\}$ the number of levels of the auto-correlation function $\xi(\tau)$ of a trial solution ρ and the number of τ values for which $\xi(\tau)$ differ from . Then, the search for admissible (but not available in ADS repositories) ADS sequences is recast as the solution of the following problem

$$Min\,(F\{\rho\}) = \alpha\,[L\{\rho\} - 3] + \beta R\{\rho\}$$

subject to $N_x \neq N_{x-ADS}$ and $N_y \neq N_{y-ADS}$ The ADSGA within the *auto-correlation space* instead of in the *pattern space*, while the constraints are still on the set of parameters defining the ADS as well as the corresponding array arrangement.

- Initialization: Random

RESULTS: $P = 6$, $Q = 6$, $K = 32$

Setting Parameters of Algorithms

GA Parameters

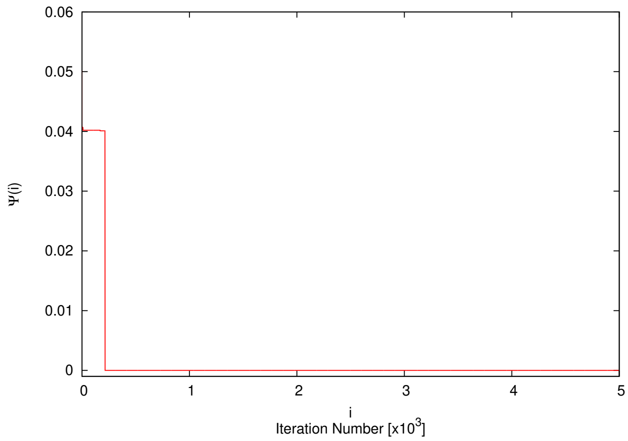
- Chromosome Dimension $C = 36\,bits$
- Population Dimension $S = 10$
- Max Iteration number $K_{max} = 5000$

Array Parameters

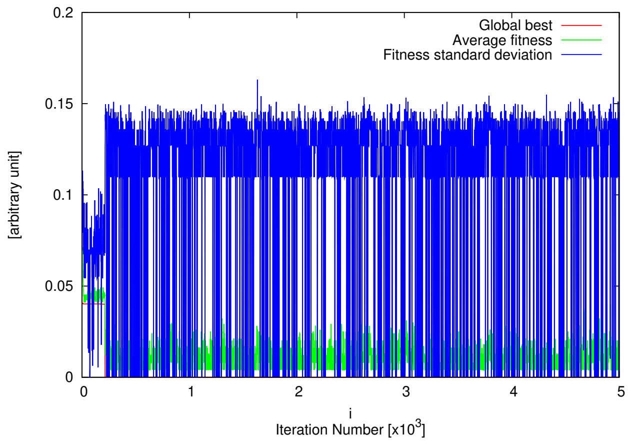
- Number of total cells $N = 32$
- Dimension X: 6
- Dimension Y: 6

Thinning

- $\nu = \frac{32}{36} = 88.9\%$

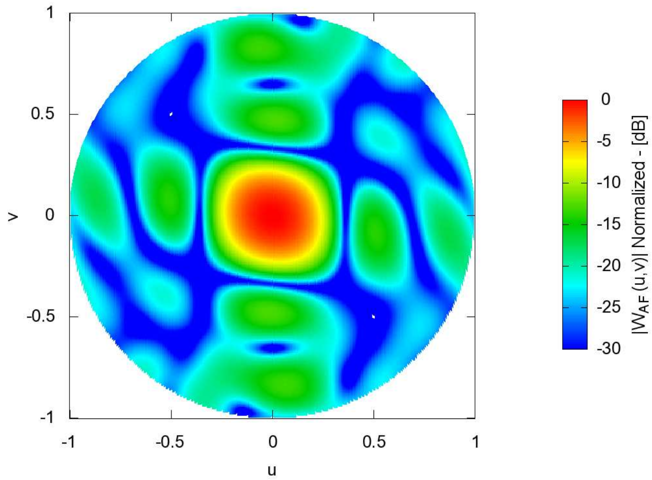


(a)

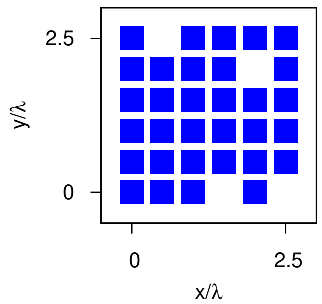


(b)

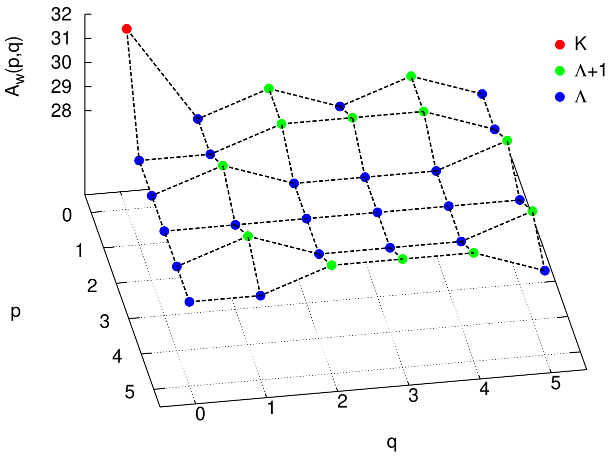
Figure 1.


1
0.5
0
-0.5
-1
v
-1
-0.5
0
0.5
1
u
0
-5
-10
-15
-20
-25
-30
$|W_{AF}(u,v)|$ Normalized - [dB]

(a)


2.5
0
y/λ
0
2.5
x/λ

(b)


32
31
30
29
28
$A_w(p,q)$
K
Λ+1
Λ
0
1
2
3
4
5
p
0
1
2
3
4
5
q

(c)

Figure 2.

RESULTS: $P = 6$, $Q = 10$, $K = 6$

Setting Parameters of Algorithms

GA Parameters

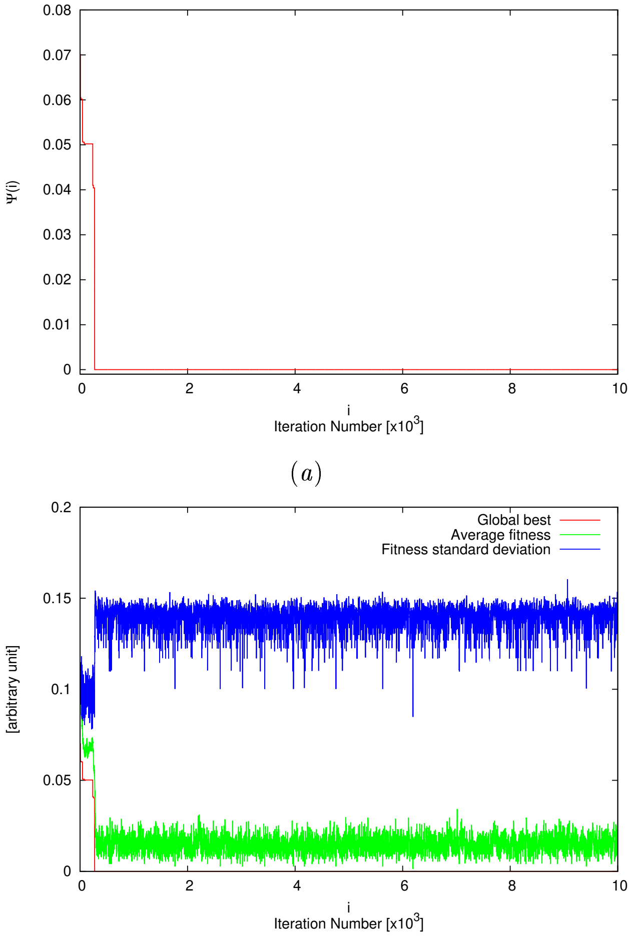
- Chromosome Dimension $C = 60\,bits$
- Population Dimension $S = 30$
- Max Iteration number $K_{max} = 10000$

Array Parameters

- Number of total cells $N = 60$
- Dimension X: 6
- Dimension Y: 10

Thinning

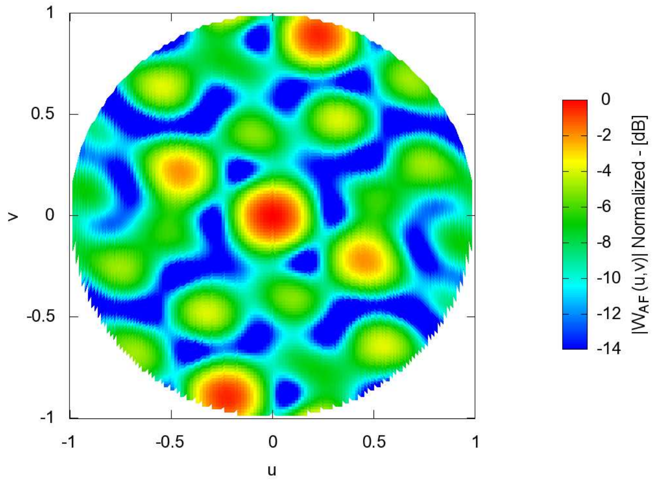
- $\nu = \frac{6}{60} = 0.10\%$



(a)

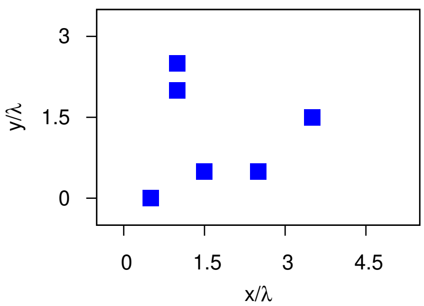
(b)

Figure 3.



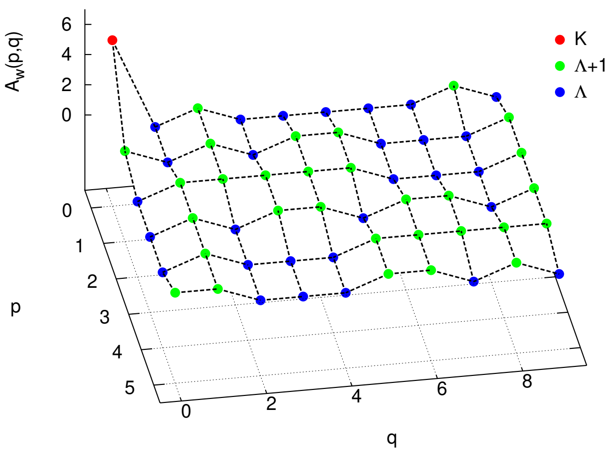
1
0.5
0
-0.5
-1
v
-1
-0.5
0
0.5
1
u
0
-2
-4
-6
-8
-10
-12
-14
$|W_{AF}(u,v)|$ Normalized - [dB]

(a)



3
1.5
0
y/λ
0
1.5
3
4.5
x/λ

(b)



$A_w(p,q)$
6
4
2
0
K
Λ+1
Λ
0
1
2
3
4
5
p
0
2
4
6
8
q

(c)

Figure 4.

RESULTS: $P = 10$, $Q = 10$, $K = 5$

Setting Parameters of Algorithms

GA Parameters

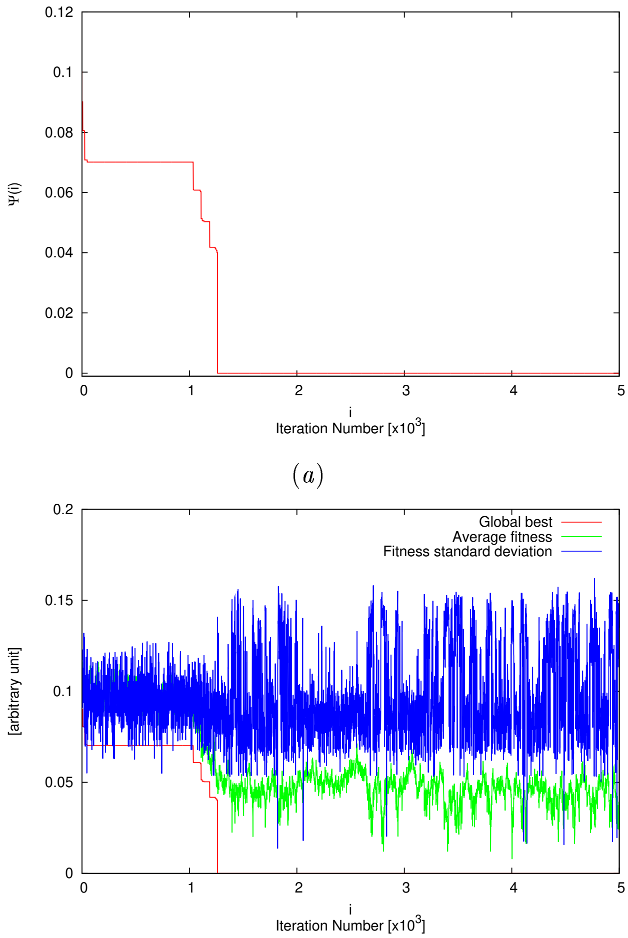
- Chromosome Dimension $C = 100\, bits$
- Population Dimension $S = 10$
- Max Iteration number $K_{max} = 5000$

Array Parameters

- Number of total cells $N = 100$
- Dimension X: 10
- Dimension Y: 10

Thinning

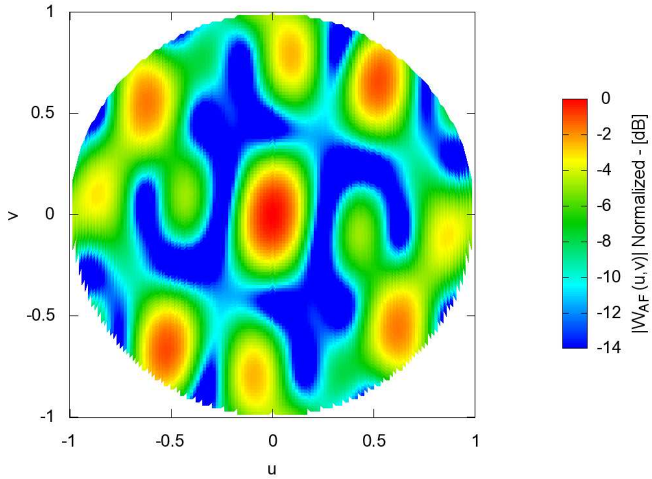
- $\nu = \frac{5}{100} = 5\%$



(a)

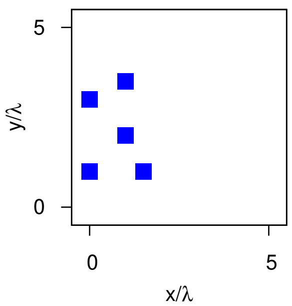
(b)

Figure 5.



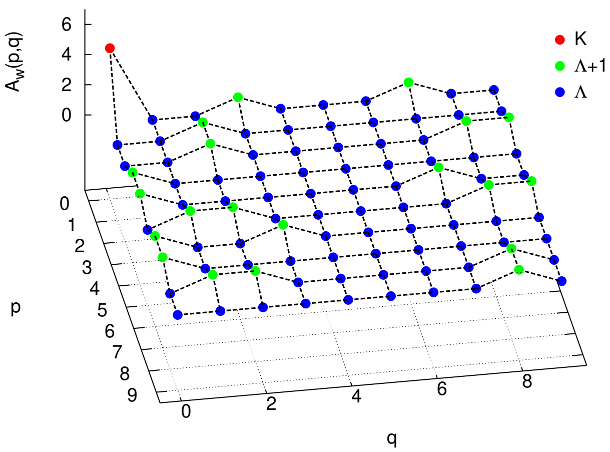
1
0.5
0
-0.5
-1
v
-1
-0.5
0
0.5
1
u
0
-2
-4
-6
-8
-10
-12
-14
|W_AF (u,v)| Normalized - [dB]

(a)



5
0
y/λ
0
5
x/λ

(b)



6
4
2
0
A_w(p,q)
K
Λ+1
Λ
0
1
2
3
4
5
6
7
8
9
p
0
2
4
6
8
q

(c)

Figure 6.

RESULTS: $P = 12$, $Q = 16$, $K = 184$

Setting Parameters of Algorithms

GA Parameters

- Chromosome Dimension $C = 192\, bits$
- Population Dimension $S = 50$
- Max Iteration number $K_{max} = 10000$

Array Parameters

- Number of total cells $N = 192$
- Dimension X: 12
- Dimension Y: 16

Thinning

- $\nu = \frac{184}{192} = 95.83\%$

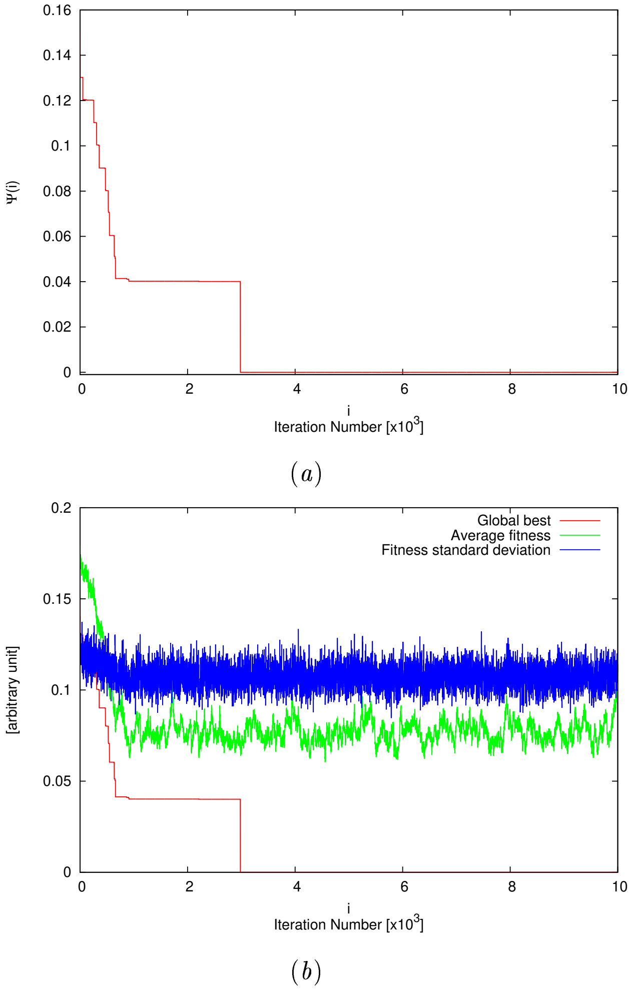
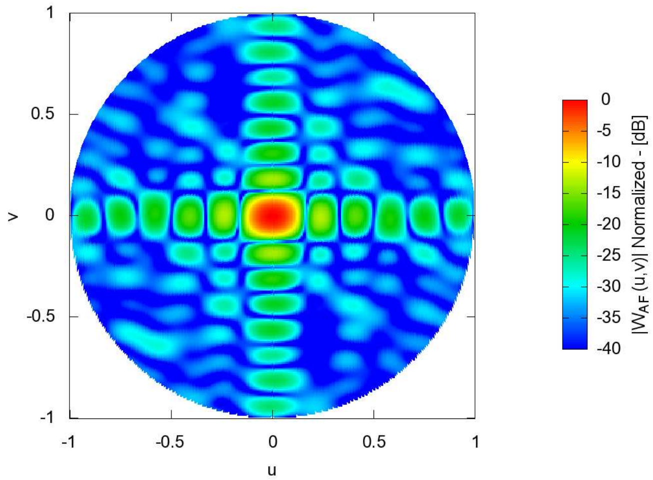
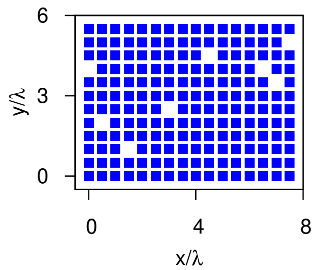


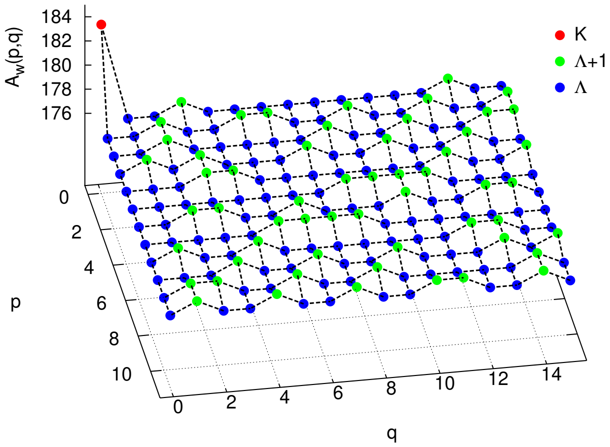
Figure 7.



(a)



(b)



(c)

Figure 8.

RESULTS: $P = 14$, $Q = 14$, $K = 7$

Setting Parameters of Algorithms

GA Parameters

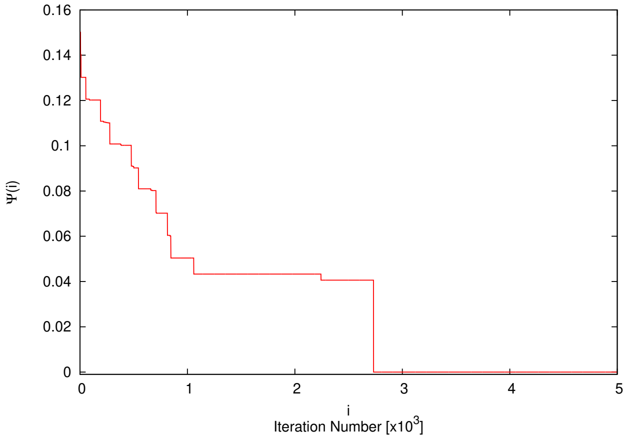
- Chromosome Dimension $C = 196\, bits$
- Population Dimension $S = 40$
- Max Iteration number $K_{max} = 5000$

Array Parameters

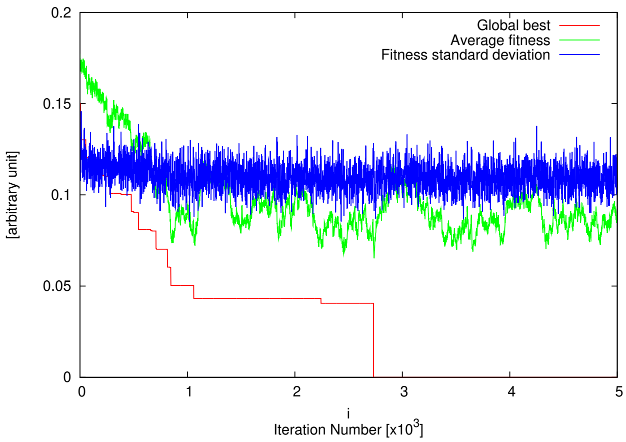
- Number of total cells $N = 196$
- Dimension X: 14
- Dimension Y: 14

Thinning

- $\nu = \frac{7}{196} = 3,57\%$

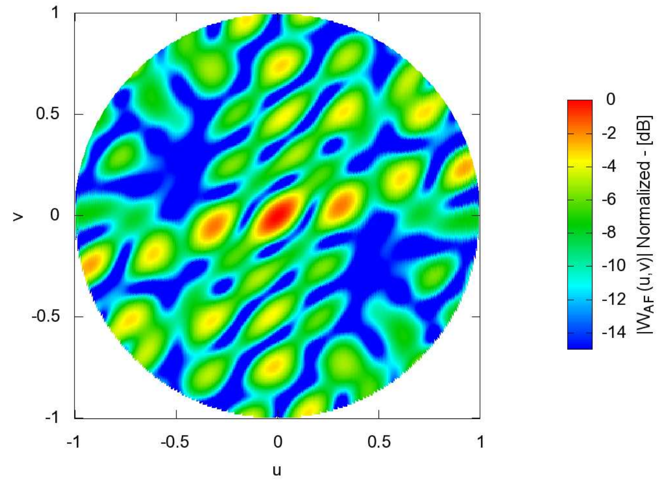


(a)

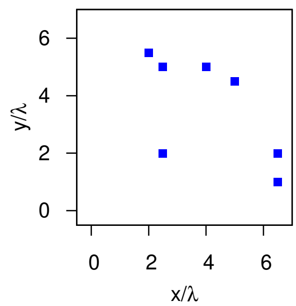


(b)

Figure 9.



(a)



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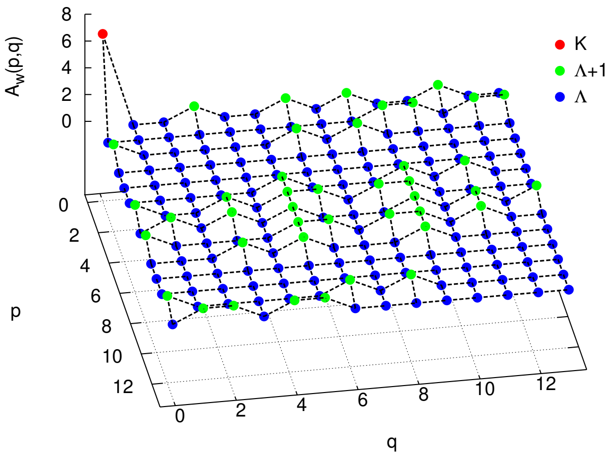


(c)

Figure 10.

RESULTS: $P = 15$, $Q = 15$, $K = 8$

Setting Parameters of Algorithms

GA Parameters

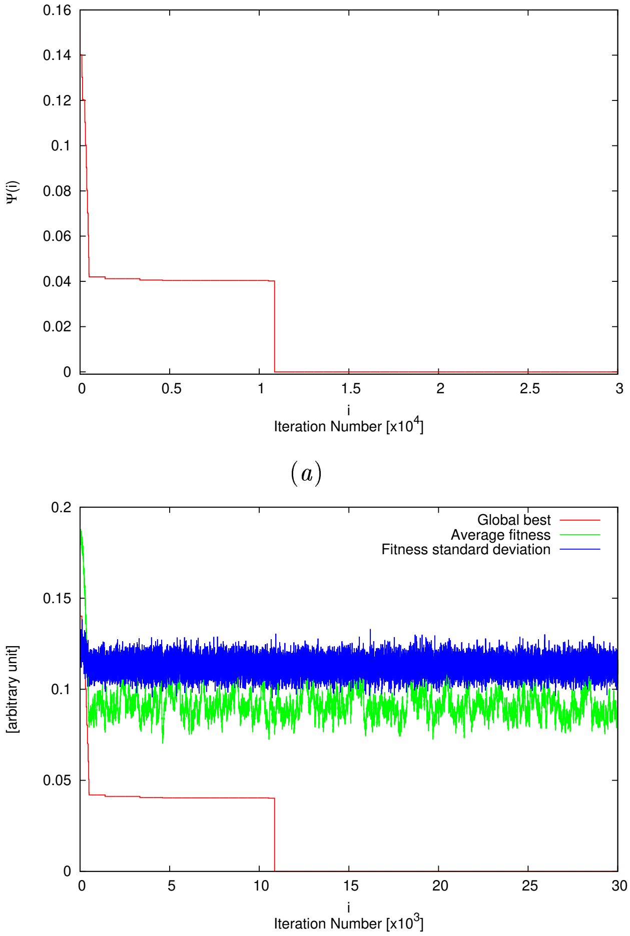
- Chromosome Dimension $C = 225\,bits$
- Population Dimension $S = 100$
- Max Iteration number $K_{max} = 30000$

Array Parameters

- Number of total cells $N = 225$
- Dimension X: 15
- Dimension Y: 15

Thinning

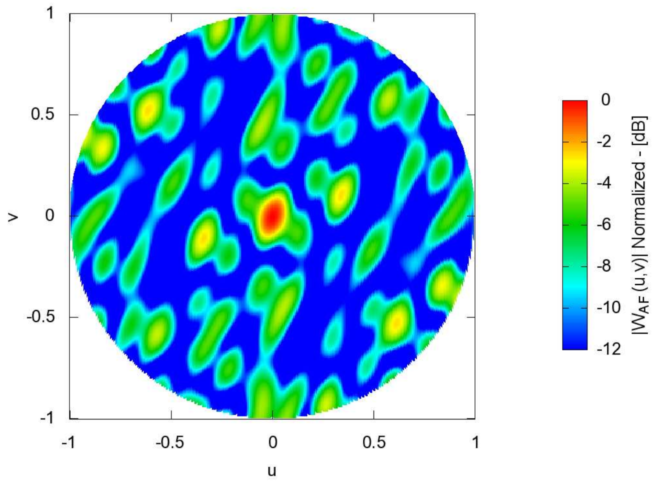
- $\nu = \frac{8}{225} = 3,55\%$



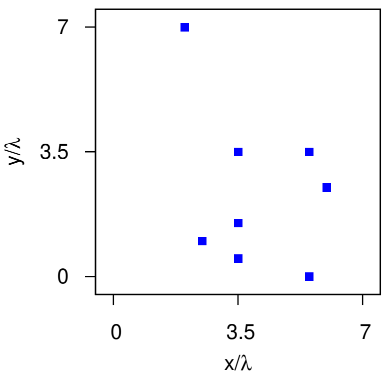
(a)

(b)

Figure 11.



(a)



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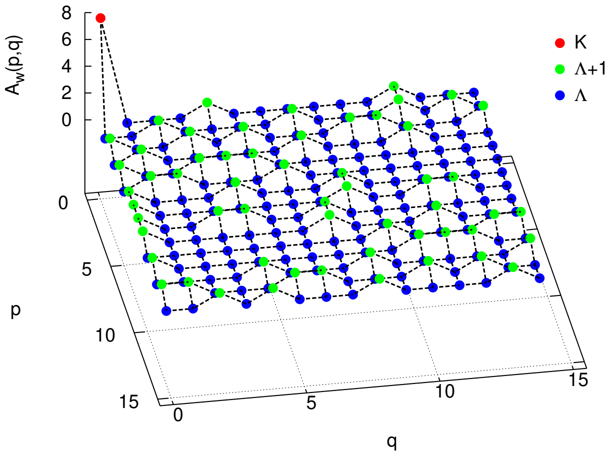

(c)

Figure 12.

P	Q	K	$\nu[\%]$	Λ	$\#(\Lambda)$
6	6	32	88.8	28	23
6	10	6	10.0	0	29
8	8	59	92.1	54	43
10	10	5	5.0	0	79
12	12	137	95.1	130	101
12	14	184	95.8	176	135
14	14	7	3.5	0	153
15	15	8	3.5	0	168

Table I.

- **Table I**: Properties of the new ADS sequences

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

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