Design of Planar Sub-Arrayed Phased Arrays Through Irregular Domino-Shaped Tiles

N. Anselmi, P. Rocca, M. Salucci, and A. Massa

Abstract

In this work, the design of planar sub-arrayed phased arrays through irregular domino-shaped tiles is presented. An innovative enumerative approach is exploited to synthesize the optimal clustering in order to obtain the maximum aperture coverage and radiation performance. Moreover, a design procedure based on optimal tiling theorems drawn from mathematical theory and exploiting a customized genetic algorithm (*GA*) optimizer to effectively minimize a suitably defined cost function is proposed. Some preliminary numerical results are presented in order to assess the potentialities of the proposed synthesis methods for small-sized arrays.

1 Numerical Validation

1.1 Preliminary Test Cases

1.1.1 Test Case #1: GA Strategy - 6x6 array

Array Analysis Parameters:

- Total Number of Elements: $M \times N = 6 \times 6 = 36$
- Spacing: $d = \lambda/2$
- Number of Samples along u: 512
- Number of Samples along v: 512
- Steering θ Direction: $\theta_s = 0$
- Steering ϕ Direction: $\phi_s = 0$

Tiling Parameters:

- Tile: Domino
- Number of Tiles Types: $L = 2$
  - Horizontal
  - Vertical
- Number of Single Tile Cell Covering: $D_i = 2, i = 1, ..., L$
- Total Number of Configurations: $C_{tot} = 6728$

Genetic Algorithm Parameters:

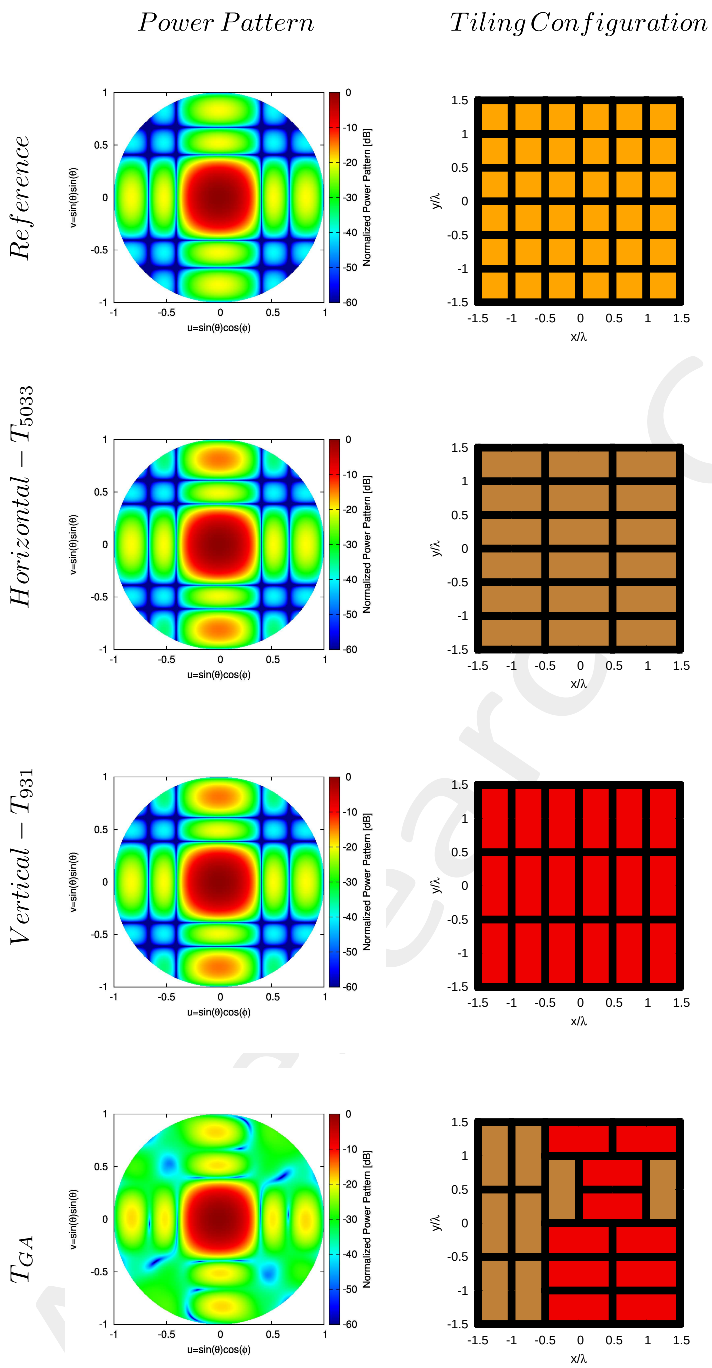
- Population Dimension: $P = 100$
- Maximum Number of Iterations: $I = 1000$
- Crossover Probability: $p_{cross} = 0.9$
- Mutation Probability: $p_{mut} = 0.01$
- Diversity Percentage: $p_{div} = 10\%$

Cost Function:

- Target SLL: $SLL_{dB}^{TARGET} = -20dB$

$$\Psi(T) = \frac{\left\{SLL\left[P_T(\theta,\phi)\right]_{dB} - SLL_{dB}^{TARGET}\right\}^2}{\left(SLL_{dB}^{TARGET}\right)^2}$$

RESULTS:



$Power\ Pattern$
$Tiling\ Configuration$
$Reference$
$Horizontal - T_{5033}$
$Vertical - T_{931}$
T_{GA}
v=sin(θ)sin(φ)
u=sin(θ)cos(φ)
Normalized Power Pattern [dB]
y/λ
x/λ

	SLL [dB]	D [dBi]	$HPBW_{az}$ [deg]	$HPBW_{el}$ [deg]	$\overline{G}$	$\Psi(T)$
Reference	-20.0	19.87	19.46	19.46	–	0.0
Horizontal	-14.50	19.84	19.46	18.63	0.0	7.6×10^{-2}
Vertical	-14.50	19.84	18.63	19.45	0.0	7.6×10^{-2}
GA	-18.51	19.87	19.14	19.10	0.7681	5.5×10^{-3}

Table 1. Pattern descriptors and fitness values for the presented solutions.

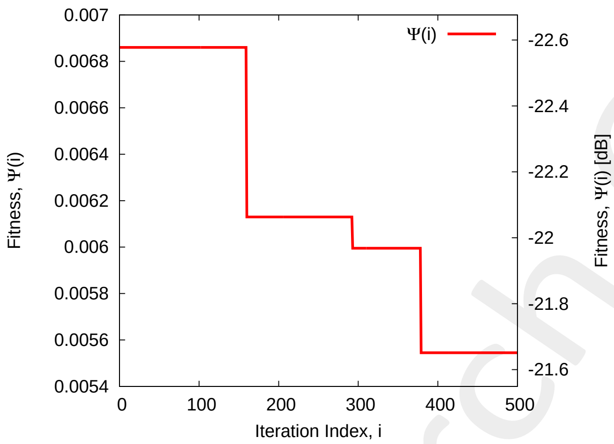
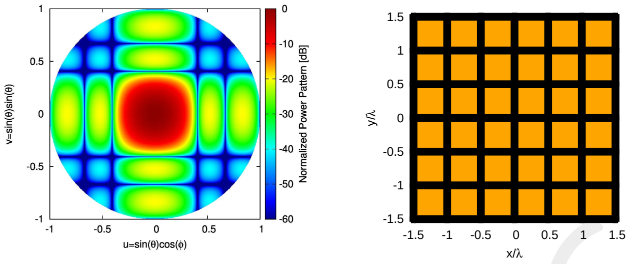


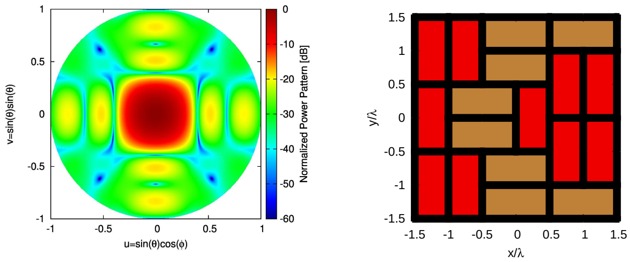
Figure 1. Fitness.

Comparison with Exhaustive Strategy:

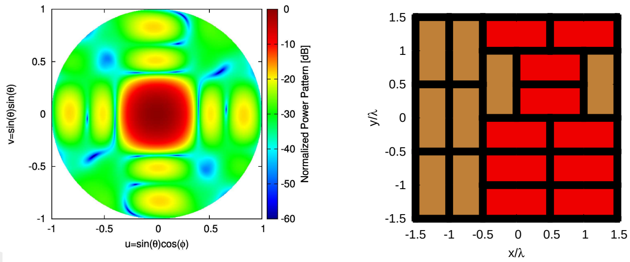
$Reference$



$Best - T_{770}$



T_{GA}



	SLL [dB]	D [dBi]	$HPBW_{az}$ [deg]	$HPBW_{el}$ [deg]	$\overline{G}$	$\Psi(T)$
$Reference$	-20.0	19.87	19.46	19.46	–	0.0
$Best$	-18.60	19.89	19.25	19.08	0.9256	4.9×10^{-3}
GA	-18.51	19.87	19.14	19.10	0.7681	5.5×10^{-3}

Table 2. Pattern descriptors and fitness values for the presented solutions.

$Conf.$	$\mathbf{w}$
$Best$	0000011011111111111111101
GA	1000011000111101111110000

Table 3. Words

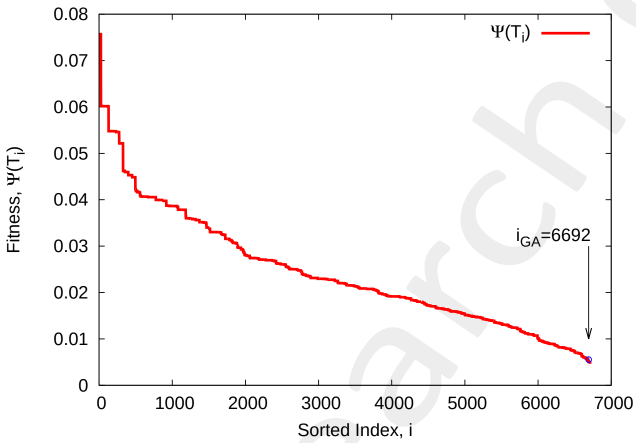


Figure 2. Ordered fitness values of the Exhaustive Strategy compared with the GA solution.

OUTCOME:

- The solution provided by the GA is very near to, but is not, the global optimum.

1.1.2 Test Case #2: GA Strategy - 6x6 array - Diversified Initial Population

Array Analysis Parameters:

- Total Number of Elements: $N = 6 \times 6 = 36$
- Spacing: $d = \lambda/2$
- Number of Samples along u: 512
- Number of Samples along v: 512
- Steering θ Direction: $\theta_s = 0$
- Steering ϕ Direction: $\phi_s = 0$

Tiling Parameters:

- Tile: Domino
- Number of Tiles Types: $L = 2$
  - Horizontal
  - Vertical
- Number of Single Tile Cell Covering: $D_i = 2, i = 1, ..., L$
- Total Number of Configurations: $C_{tot} = 6728$

Genetic Algorithm Parameters:

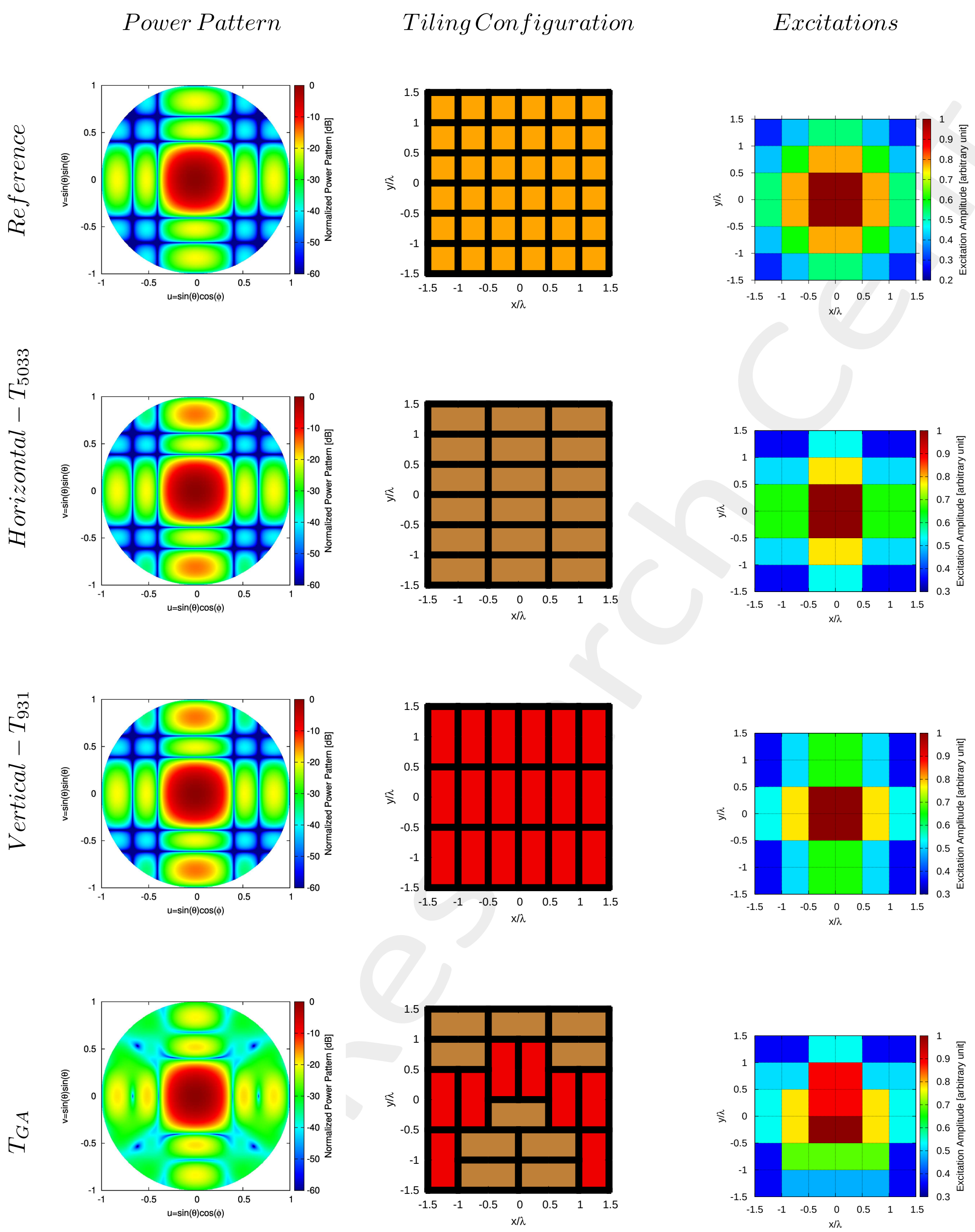
- Population Dimension: $P = 50$
- Maximum Number of Iterations: $I = 10$
- Crossover Probability: $p_{cross} = 0.9$
- Mutation Probability: $p_{mut} = 0.01$
- Diversified Percentage: $p_{div} = 10\%$

Cost Function:

- Target SLL: $SLL_{dB}^{TARGET} = -20dB$

$$\Psi(T) = \frac{\left\{SLL\left[P_T(\theta, \phi)\right]_{dB} - SLL_{dB}^{TARGET}\right\}^2}{\left(SLL_{dB}^{TARGET}\right)^2}$$

RESULTS:


Power Pattern
Tiling Configuration
Excitations
Reference
Horizontal − T_{5033}
Vertical − T_{931}
T_{GA}
u=sin(θ)cos(φ)
v=sin(θ)sin(φ)
Normalized Power Pattern [dB]
x/λ
y/λ
Excitation Amplitude [arbitrary unit]

	SLL [dB]	D [dBi]	$HPBW_{az}$ [deg]	$HPBW_{el}$ [deg]	$\overline{G}$	$\Psi(T)$
$Reference$	-20.0	19.87	19.46	19.46	–	0.0
$Horizontal$	-14.50	19.84	19.46	18.63	0.0	7.6×10^{-2}
$Vertical$	-14.50	19.84	18.63	19.45	0.0	7.6×10^{-2}
GA	-18.597	19.89	19.08	19.25	0.9256	4.9×10^{-3}

Table 1. Pattern descriptors and fitness values for the presented solutions.

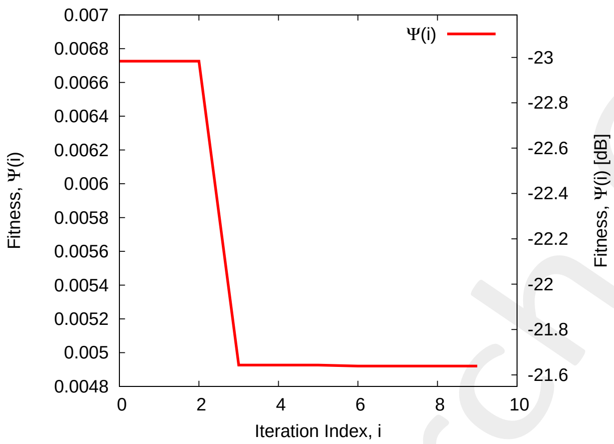


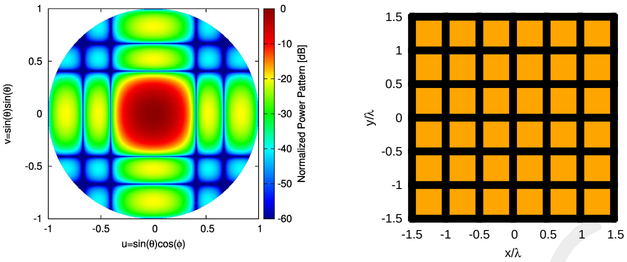
Figure 1. Fitness.

$Conf.$	$\mathbf{w}$
$Best$	000001101111111111111111101
GA	100001100011110111111110000

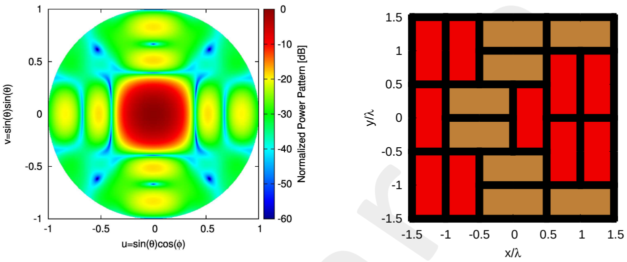
Table 3. Words

Comparison with Exhaustive Strategy:

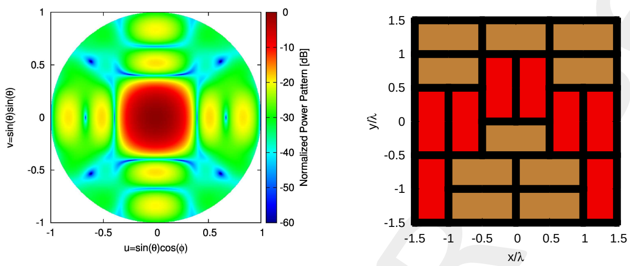
$Reference$



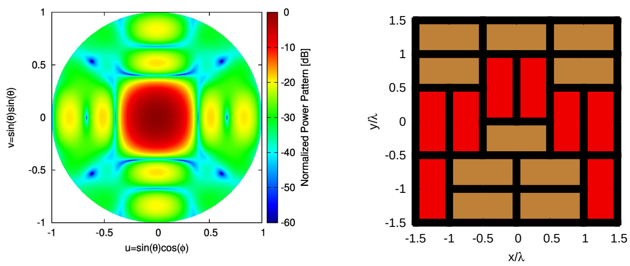
$Best - T_{770}$



$Best - T_{1435}$



T_{GA}



	SLL [dB]	D [dBi]	$HPBW_{az}$ [deg]	$HPBW_{el}$ [deg]	$\Psi(T)$
$Reference$	-20.0	19.87	19.46	19.46	0.0
$Best - T_{770}$	-18.597	19.89	19.25	19.08	4.9×10^{-3}
$Best - T_{1435}$	-18.597	19.89	19.08	19.25	4.9×10^{-3}
GA	-18.597	19.89	19.08	19.25	4.9×10^{-3}

Table 2. Pattern descriptors and fitness values for the presented solutions.

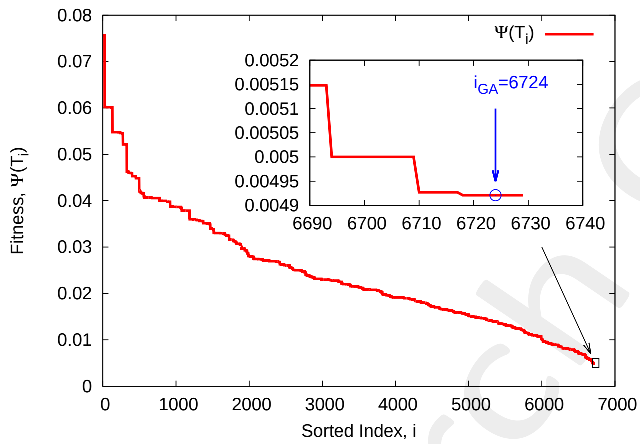


Figure 2. Ordered fitness values of the Exhaustive Strategy compared with the GA solution.

$Conf$	**w**
$Best - T_{770}$	0000011011111111111111111
$Conf - T_{1077}$	0000011111111111111111111
$Conf - T_{1108}$	0000011111112111111111111
$Conf - T_{1370}$	0000101111011110111100001
$Conf - T_{1417}$	0000101111012110111100001
$Conf - T_{1435}$	**0000101111012210111100001**
$Conf - T_{3691}$	1000011110111101111010000
$Conf - T_{3709}$	1000011110112101111010000
$Conf - T_{3727}$	1000011110122101111010000
$Conf - T_{6445}$	1111111111111111101100000
$Conf - T_{6449}$	1111111111111111111100000
$Conf - T_{6480}$	1111111111112111111100000
GA	**0000101111012210111100001**

Table 3. The global optimal solutions and GA solution words.

OUTCOME:

- The solution provided by the GA belongs to the set of optimal solutions.

References

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