A customized genetic algorithm for the synthesis of adaptive thinned array with constrained directivity

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Abstract

An innovative adaptive nulling strategy based on reconfigurable thinned arrays is studied in this report. A customized version of the genetic algorithms exploiting ad-hoc operators devoted to keep constant the number of elements instantaneously active is applied to optimize the on/off status of the switches to maximize the signal-to-interference-plus-noise ratio at the antenna output. The performances of the technique have been analyzed varying the number of array elements and the number of interferences within a static scenario.

TEST CASE 5 - 32 Elements - Fixed Scenario, Single Interference - $\eta \in [0.00 - 1.00]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a single interference.

Test Case Description

- Number of Elements $N = 32$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\, dB$
- Interference Power: $30\, dB$
- Noise Power: $-30\, dB$
- Number of Interferences: $N^I = 1$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$

Optimization Approach: GA

- Number of Variables: $X = 32$ $(\alpha_n,\, n = 1, ..., N)$
- Population: 16
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.00$
- Maximum Thinning Coefficient: $\eta_{max} = 1.00$
- Number of Repetitions for Statistical Analysis: 20

GA - 32 Elements - Single Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$

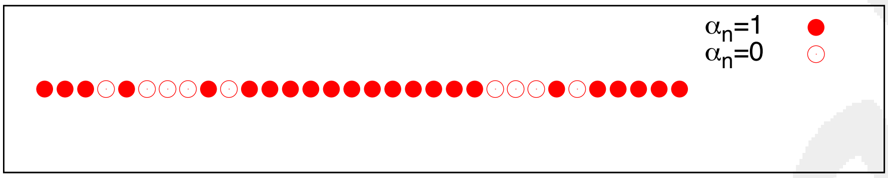

Fig.16 - Thinning Configuration

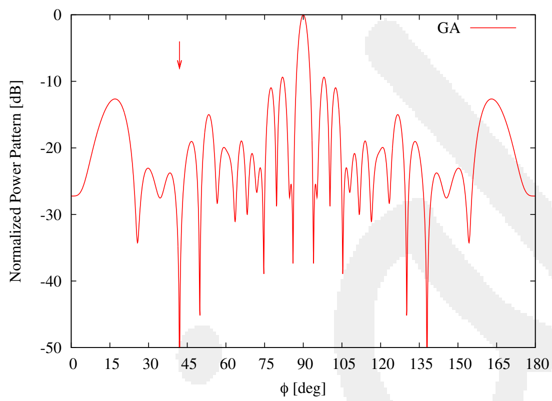

Fig.17 - Pattern

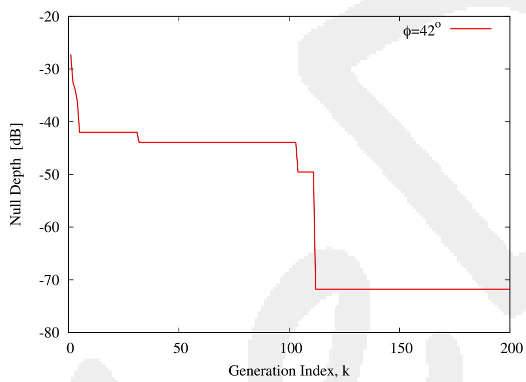

Fig.18 - Nulls Depth

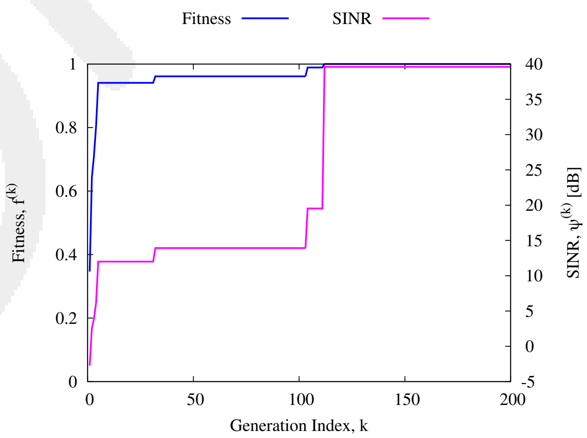

Fig.19 - Fitness - SINR

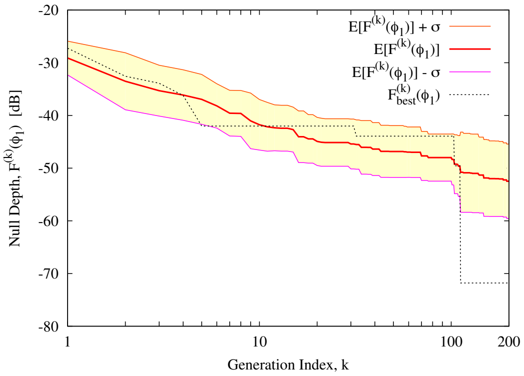

Fig.20 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

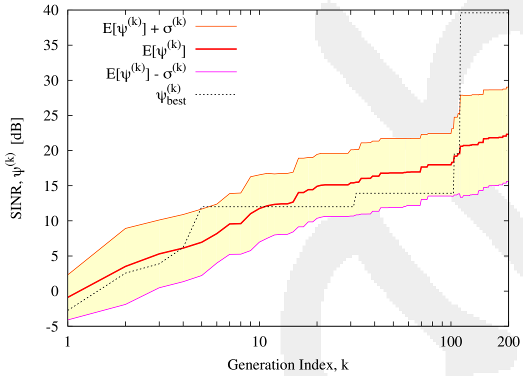

Fig.21 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	*Nr. Active Elements*	$SINR\,[dB]$
GA	-71.79	23	39.60

Tab.6 - GA Simulation Results Analysis

TEST CASE 6 - 32 Elements - Fixed Scenario, Single Interference - $\eta \in [0.50 - 0.70]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a single interference.

Test Case Description

- Number of Elements $N = 32$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 1$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$

Optimization Approach: GA

- Number of Variables: $X = 32$ (α_n, $n = 1, ..., N$)
- Population: 16
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.50$
- Maximum Thinning Coefficient: $\eta_{max} = 0.70$
- Number of Repetitions for Statistical Analysis: 20

GA - 32 Elements - Single Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$

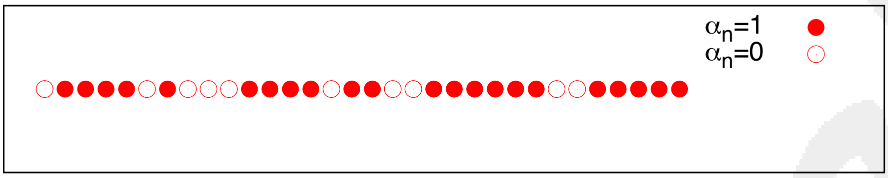

Fig.22 - Thinning Configuration

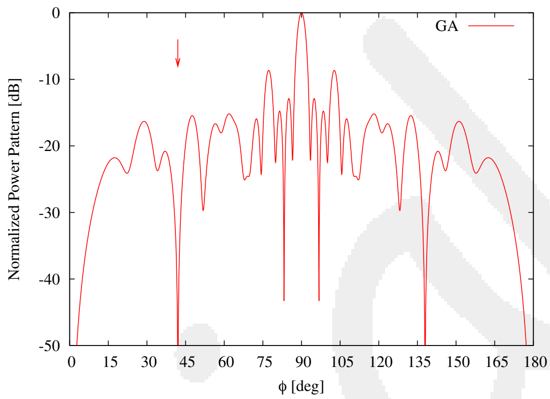

Fig.23 - Pattern

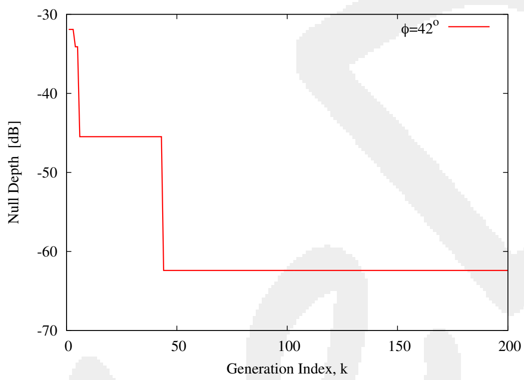

Fig.24 - Nulls Depth

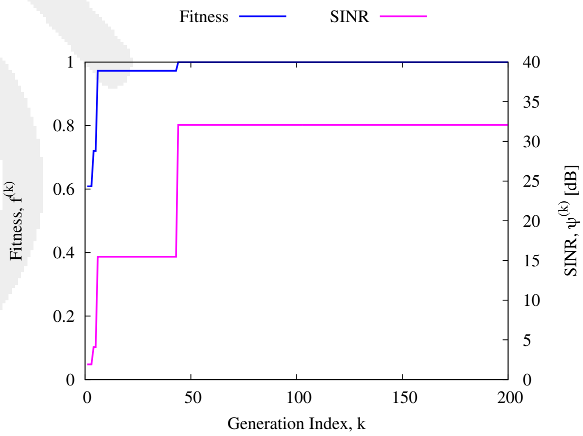

Fig.25 - Fitness - SINR

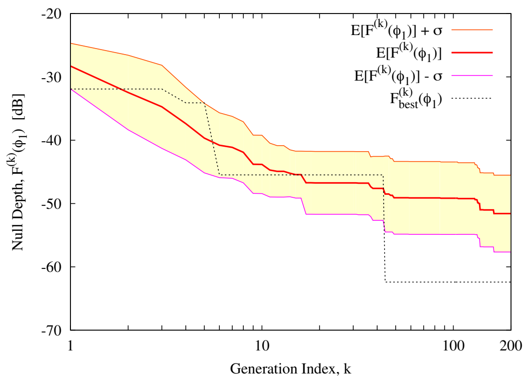

Fig.26 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

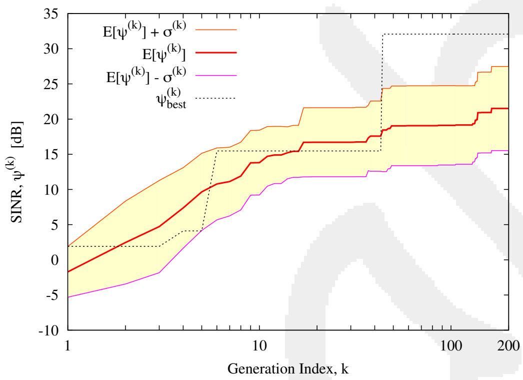

Fig.27 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	*Nr. Active Elements*	$SINR\,[dB]$
GA	-62.41	22	32.08

Tab.7 - GA Simulation Results Analysis

TEST CASE 7 - 32 Elements - Fixed Scenario, Single Interference - $\eta \in [0.60 - 0.60]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a single interference.

Test Case Description

- Number of Elements $N = 32$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 1$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$

Optimization Approach: GA

- Number of Variables: $X = 32$ (α_n, $n = 1, ..., N$)
- Population: 16
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.60$
- Maximum Thinning Coefficient: $\eta_{max} = 0.60$
- Number of Repetitions for Statistical Analysis: 20

GA - 32 Elements - Single Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$

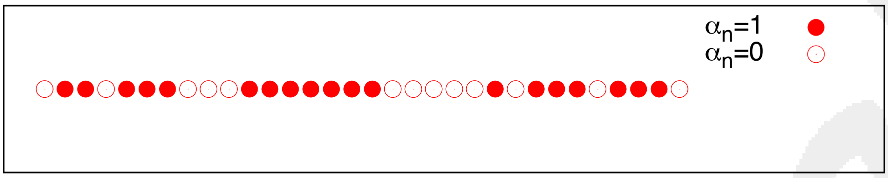

Fig.28 - Thinning Configuration

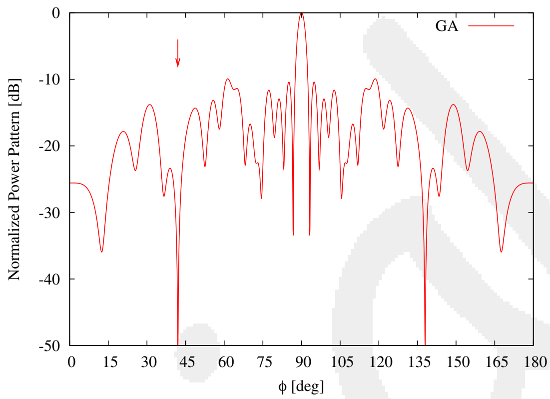

Fig.29 - Pattern

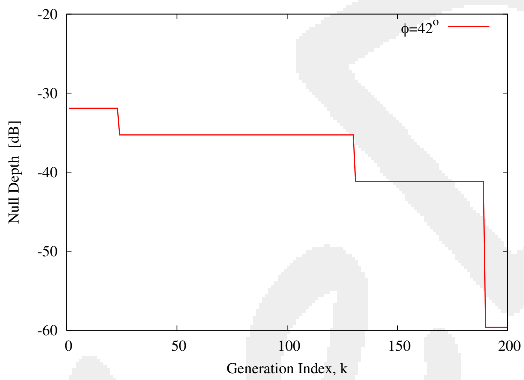

Fig.30 - Nulls Depth

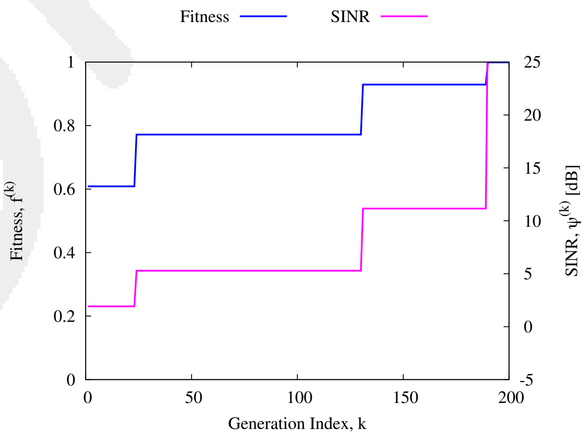

Fig.31 - Fitness - SINR

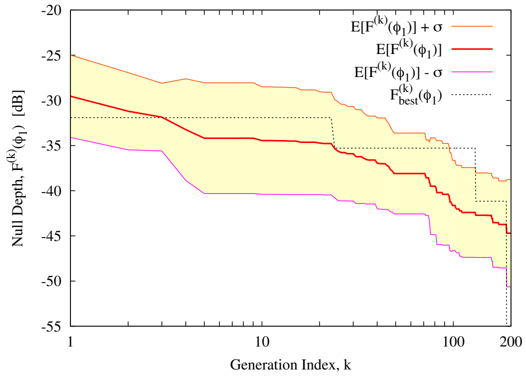

Fig.32 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

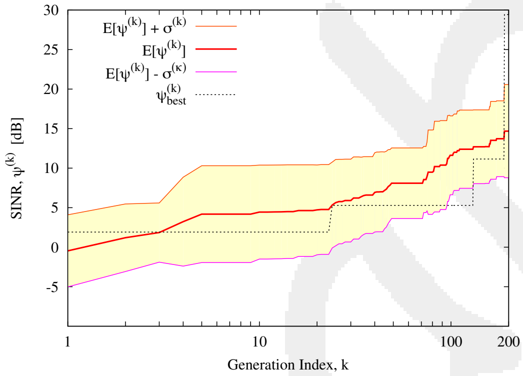

Fig.33 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$Nr. Active Elements$	$SINR\,[dB]$
GA	-53.18	19	23.14

Tab.8 - GA Simulation Results Analysis

TEST CASE 8 - 32 Elements - Fixed Scenario, Double Interference - $\eta \in [0.00 - 1.00]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a double interference.

Test Case Description

- Number of Elements $N = 32$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 2$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$

Optimization Approach: GA

- Number of Variables: $X = 32$ (α_n, $n = 1, ..., N$)
- Population: 16
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.00$
- Maximum Thinning Coefficient: $\eta_{max} = 1.00$
- Number of Repetitions for Statistical Analysis: 20

GA - 32 Elements - Double Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$

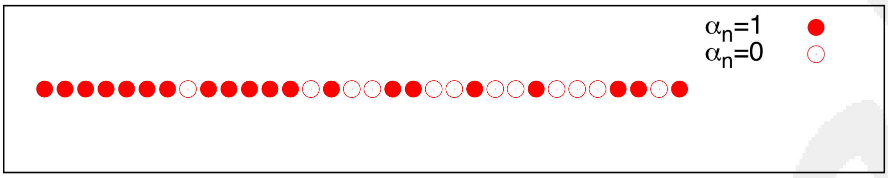

Fig.34 - Thinning Configuration

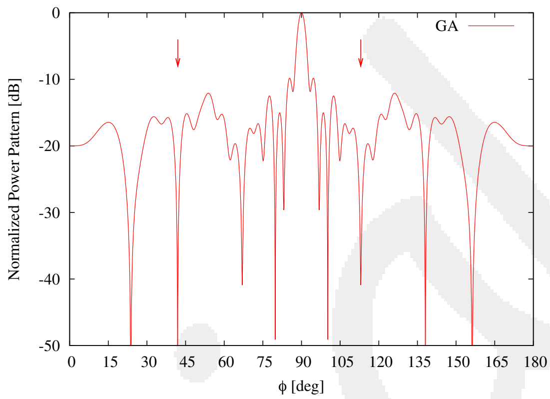

Fig.35 - Pattern

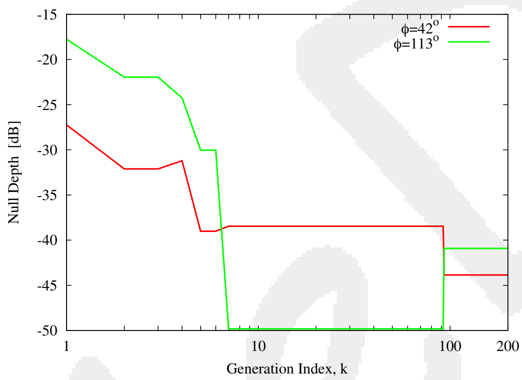

Fig.36 - Nulls Depth

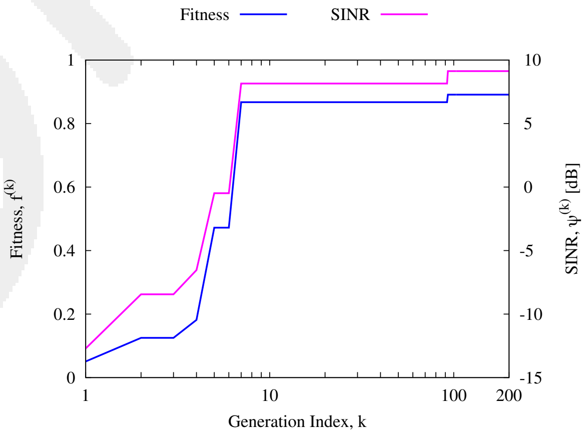

Fig.37 - Fitness - SINR

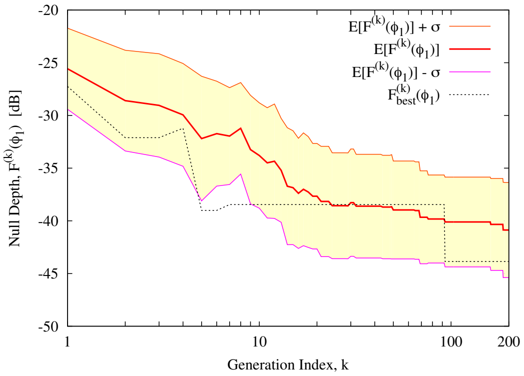

Fig.38 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

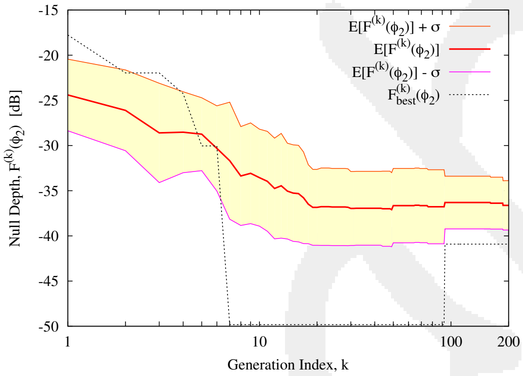

Fig.39 - Null Depth $\theta_2^i = 90°$, $\phi_2^i = 113°$ Statistics

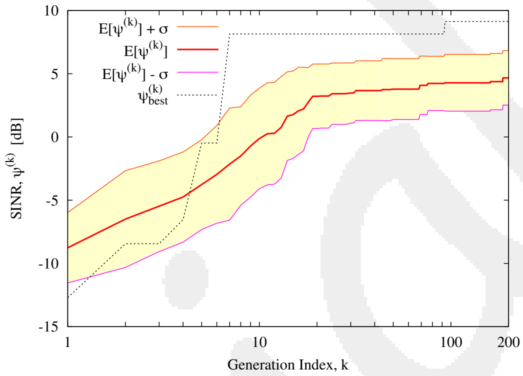

Fig.40 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$AF(\theta_2^i, \phi_2^i)$	*Nr. Active Elements*	$SINR\,[dB]$
GA	-43.85	-40.92	20	9.13

Tab.9 - GA Simulation Results Analysis

TEST CASE 9 - 32 Elements - Fixed Scenario, Double Interference - $\eta \in [0.50 - 0.70]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a double interference.

Test Case Description

- Number of Elements $N = 32$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 2$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$

Optimization Approach: GA

- Number of Variables: $X = 32$ (α_n, $n = 1, ..., N$)
- Population: 16
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.50$
- Maximum Thinning Coefficient: $\eta_{max} = 0.70$
- Number of Repetitions for Statistical Analysis: 20

GA - 32 Elements - Double Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$

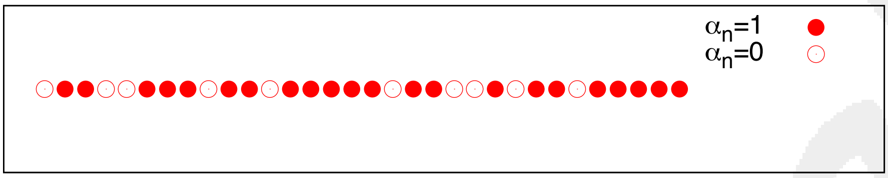

Fig.41 - Thinning Configuration

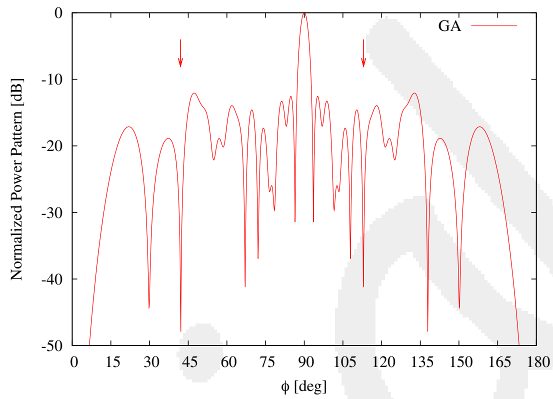

Fig.42 - Pattern

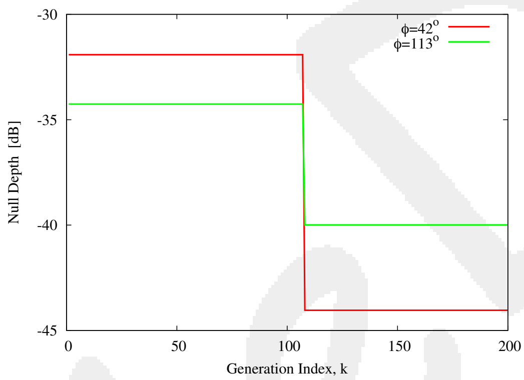

Fig.43 - Nulls Depth

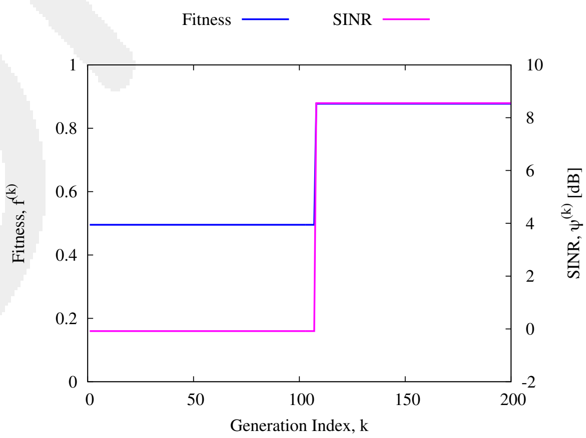

Fig.44 - Fitness - SINR

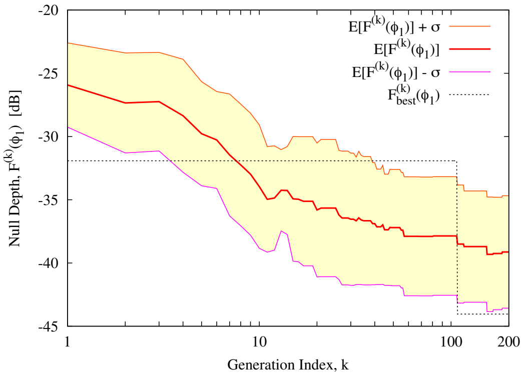

Fig.45 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

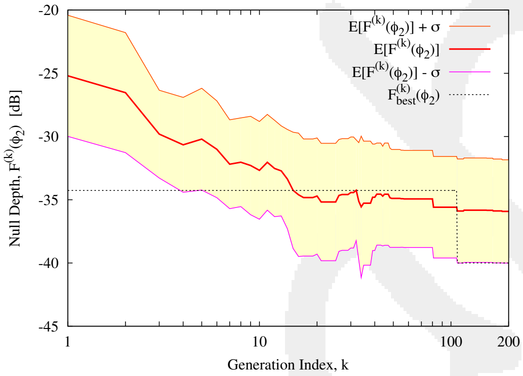

Fig.46 - Null Depth $\theta_2^i = 90°$, $\phi_2^i = 113°$ Statistics

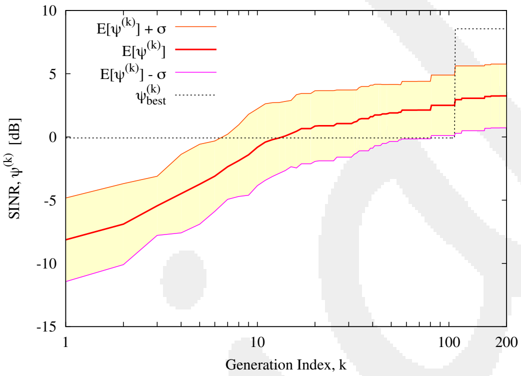

Fig.47 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$AF(\theta_2^i, \phi_2^i)$	$Nr. Active Elements$	$SINR\,[dB]$
GA	-44.04	-39.99	22	8.55

Tab.10 - GA Simulation Results Analysis

TEST CASE 10 - 32 Elements - Fixed Scenario, Double Interference - $\eta \in [0.60 - 0.60]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a double interference.

Test Case Description

- Number of Elements $N = 32$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 2$
- Interference Direction Of Arrival: $\theta^i_1 = 90°$, $\phi^i_1 = 42°$, $\theta^i_2 = 90°$, $\phi^i_2 = 113°$

Optimization Approach: GA

- Number of Variables: $X = 32$ (α_n, $n = 1, ..., N$)
- Population: 16
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.60$
- Maximum Thinning Coefficient: $\eta_{max} = 0.60$
- Number of Repetitions for Statistical Analysis: 20

GA - 32 Elements - Double Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$

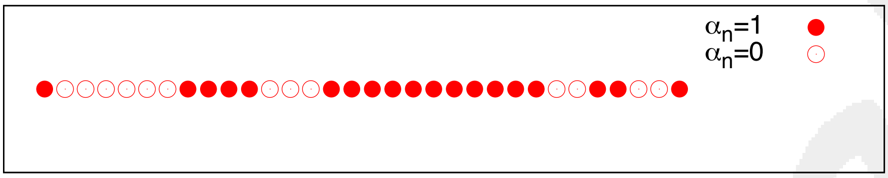

Fig.48 - Thinning Configuration

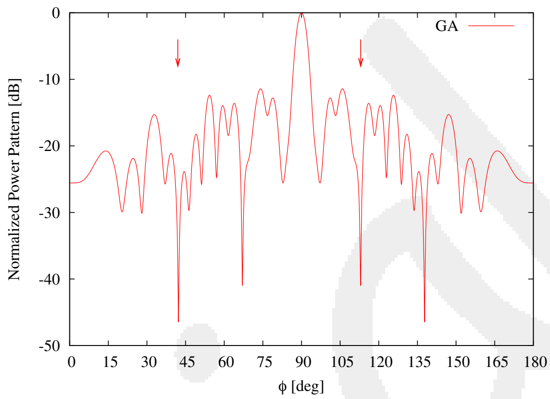

Fig.49 - Pattern

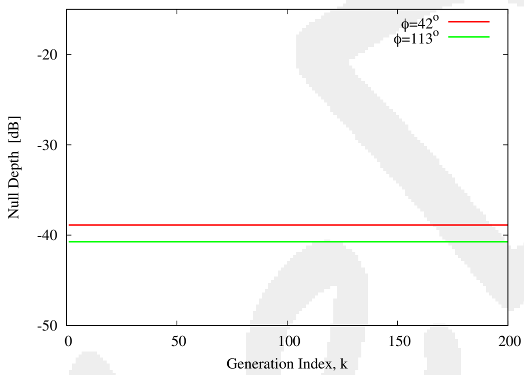

Fig.50 - Nulls Depth

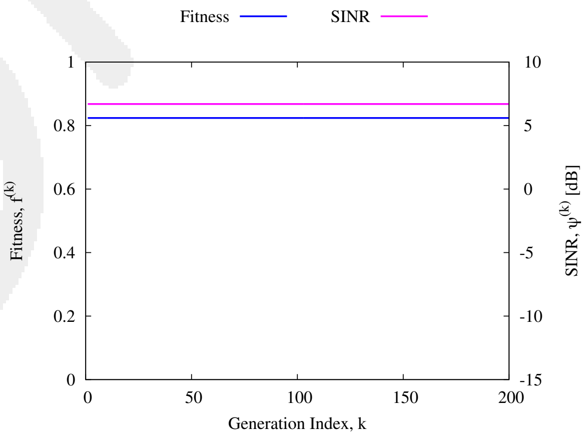

Fig.51 - Fitness - SINR

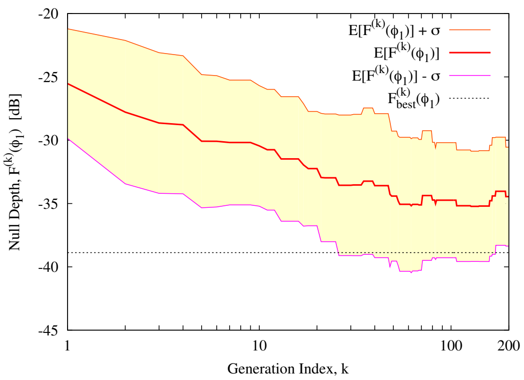

Fig.52 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

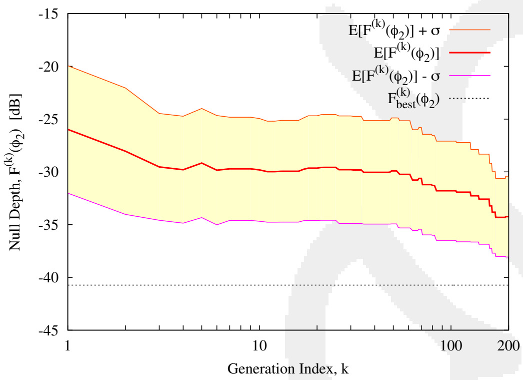

Fig.53 - Null Depth $\theta_2^i = 90°$, $\phi_2^i = 113°$ Statistics

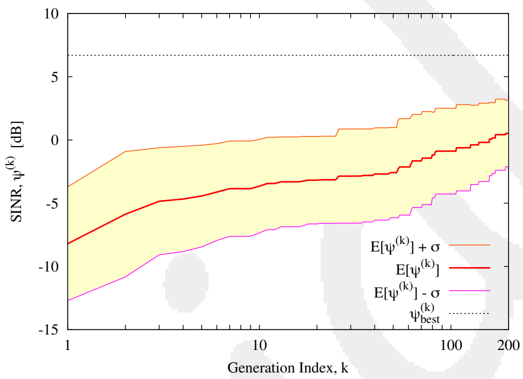

Fig.54 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$AF(\theta_2^i, \phi_2^i)$	*Nr. Active Elements*	$SINR\,[dB]$
GA	-38.87	-40.73	19	6.69

Tab.11 - GA Simulation Results Analysis

TEST CASE 11 - 32 Elements - Fixed Scenario, Triple Interference - $\eta \in [0.00 - 1.00]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a triple interference.

Test Case Description

- Number of Elements $N = 32$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 3$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$, $\theta_3^i = 90°$, $\phi_3^i = 164°$

Optimization Approach: GA

- Number of Variables: $X = 32$ (α_n, $n = 1, ..., N$)
- Population: 16
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.00$
- Maximum Thinning Coefficient: $\eta_{max} = 1.00$
- Number of Repetitions for Statistical Analysis: 20

GA - 32 Elements - Triple Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$, $\theta_3^i = 90°$, $\phi_3^i = 164°$

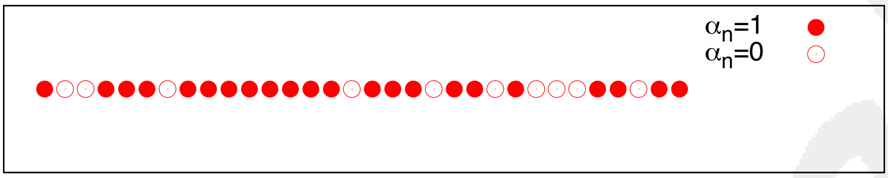

Fig.55 - Thinning Configuration

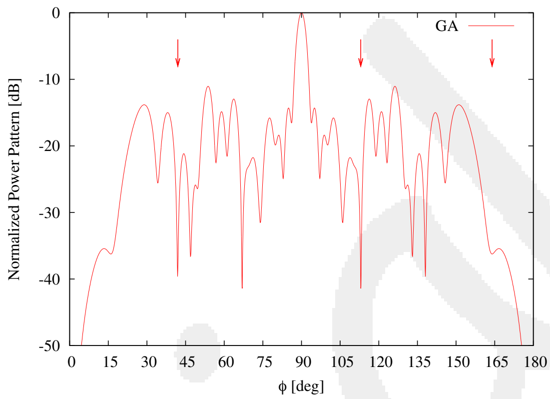

Fig.56 - Pattern

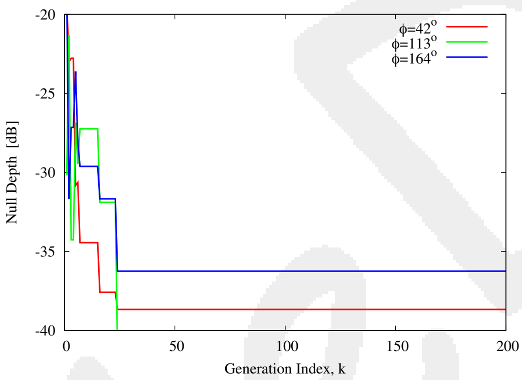

Fig.57 - Nulls Depth

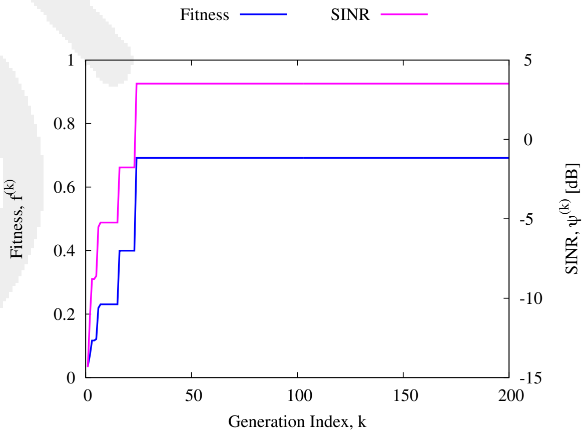

Fig.58 - Fitness - SINR

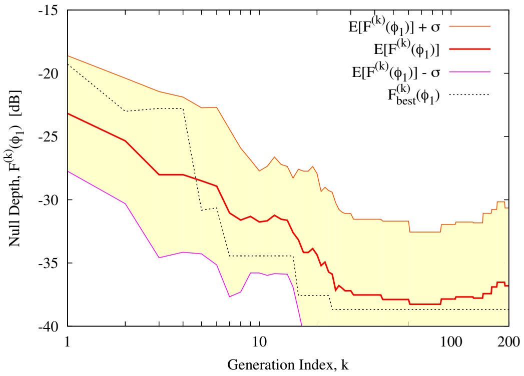

Fig.59 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

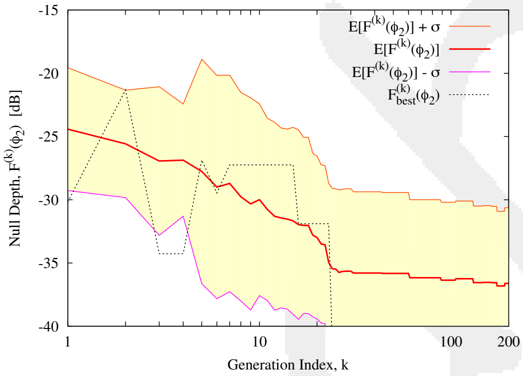

Fig.60 - Null Depth $\theta_2^i = 90°$, $\phi_2^i = 113°$ Statistics

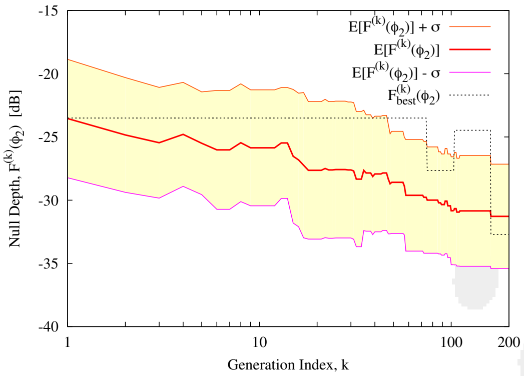

Fig.61 - Null Depth $\theta_3^i = 90°$, $\phi_3^i = 164°$ Statistics

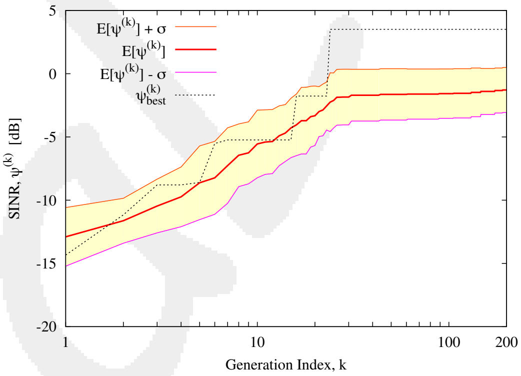

Fig.62 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$AF(\theta_2^i, \phi_2^i)$	$AF(\theta_3^i, \phi_3^i)$	$Nr. Active Elements$	$SINR [dB]$
GA	-38.67	-41.41	-36.25	22	3.51

Tab.12 - GA Simulation Results Analysis

TEST CASE 12 - 32 Elements - Fixed Scenario, Triple Interference - $\eta \in [0.50 - 0.70]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a triple interference.

Test Case Description

- Number of Elements $N = 32$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 3$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$, $\theta_3^i = 90°$, $\phi_3^i = 164°$

Optimization Approach: GA

- Number of Variables: $X = 32$ (α_n, $n = 1, ..., N$)
- Population: 16
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.50$
- Maximum Thinning Coefficient: $\eta_{max} = 0.70$
- Number of Repetitions for Statistical Analysis: 20

GA - 32 Elements - Triple Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$, $\theta_3^i = 90°$, $\phi_3^i = 164°$

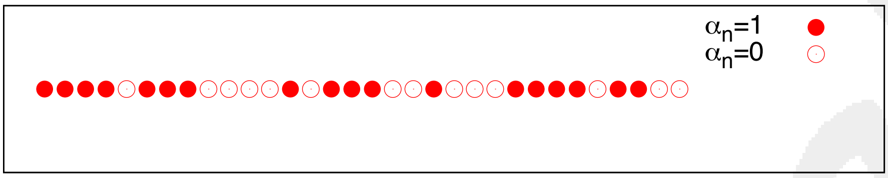

Fig.63 - Thinning Configuration

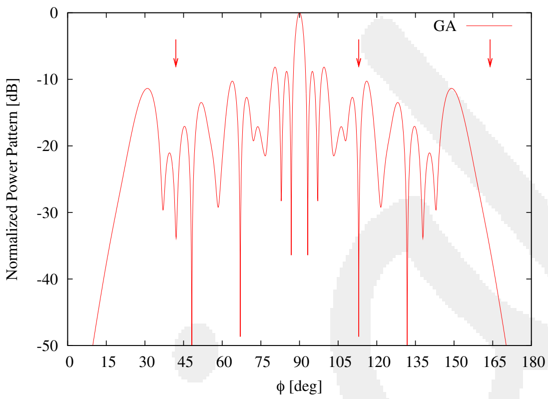

Fig.64 - Pattern

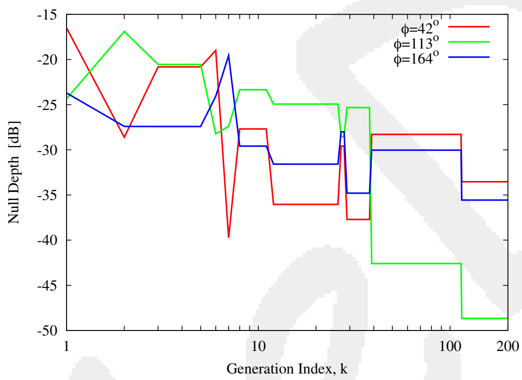

Fig.65 - Nulls Depth

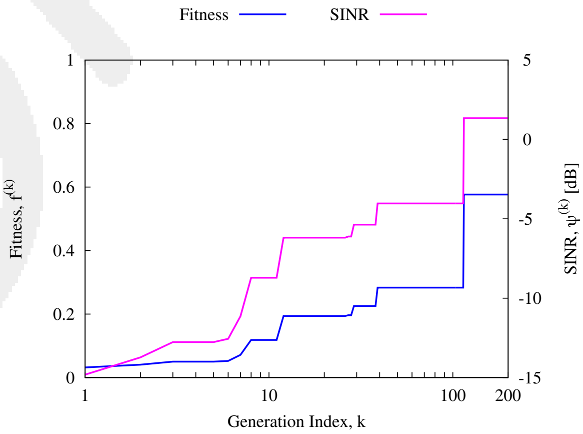

Fig.66 - Fitness - SINR

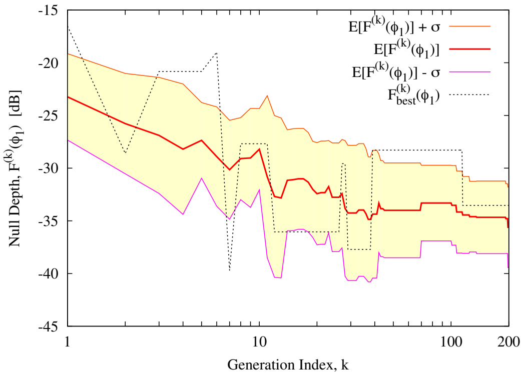

Fig.67 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

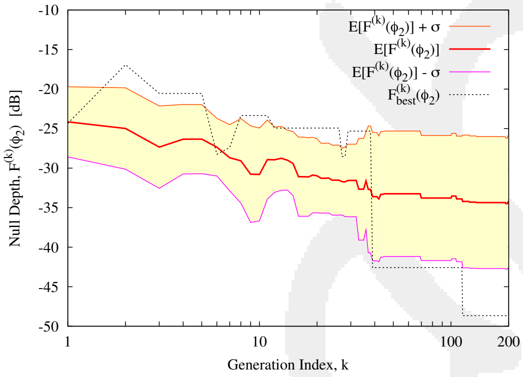

Fig.68 - Null Depth $\theta_2^i = 90°$, $\phi_2^i = 113°$ Statistics

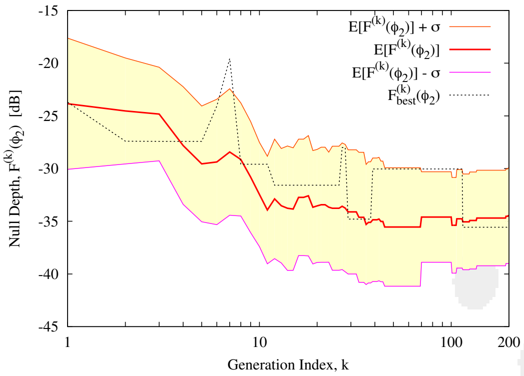

Fig.69 - Null Depth $\theta_3^i = 90°$, $\phi_3^i = 164°$ Statistics

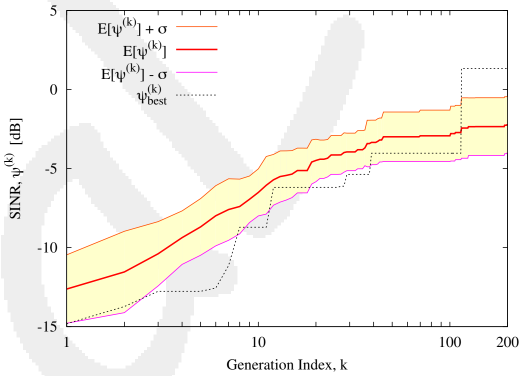

Fig.70 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$AF(\theta_2^i, \phi_2^i)$	$AF(\theta_3^i, \phi_3^i)$	$Nr. Active Elements$	$SINR [dB]$
GA	-33.53	-48.66	-35.56	18	1.34

Tab.13 - GA Simulation Results Analysis

TEST CASE 13 - 32 Elements - Fixed Scenario, Triple Interference - $\eta \in [0.60 - 0.60]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a triple interference.

Test Case Description

- Number of Elements $N = 32$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 3$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$, $\theta_3^i = 90°$, $\phi_3^i = 164°$

Optimization Approach: GA

- Number of Variables: $X = 32$ (α_n, $n = 1, ..., N$)
- Population: 16
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.60$
- Maximum Thinning Coefficient: $\eta_{max} = 0.60$
- Number of Repetitions for Statistical Analysis: 20

GA - 32 Elements - Triple Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$, $\theta_3^i = 90°$, $\phi_3^i = 164°$

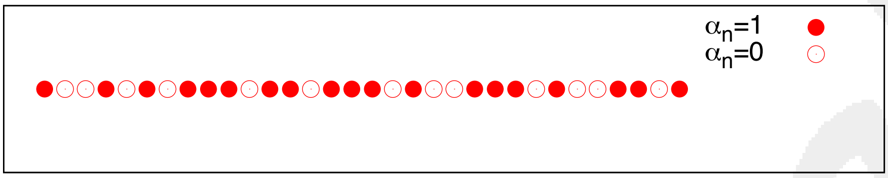

Fig.71 - Thinning Configuration

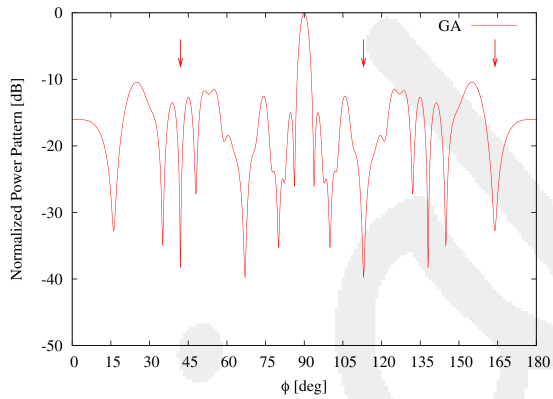

Fig.72 - Pattern

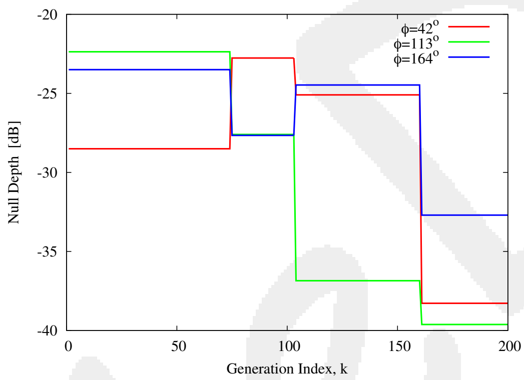

Fig.73 - Nulls Depth

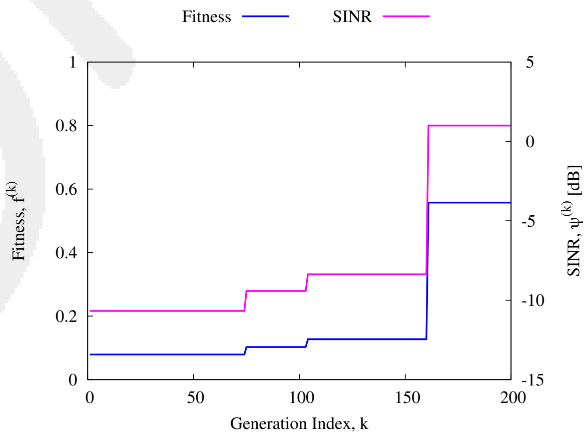

Fig.74 - Fitness - SINR

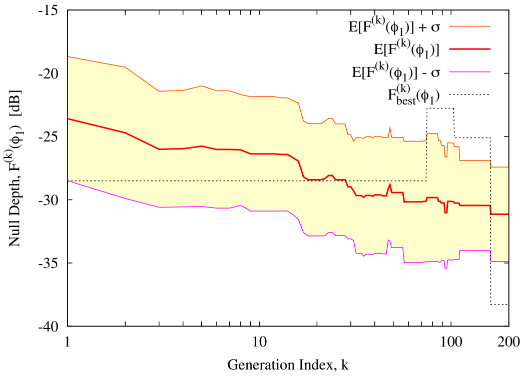

Fig.75 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

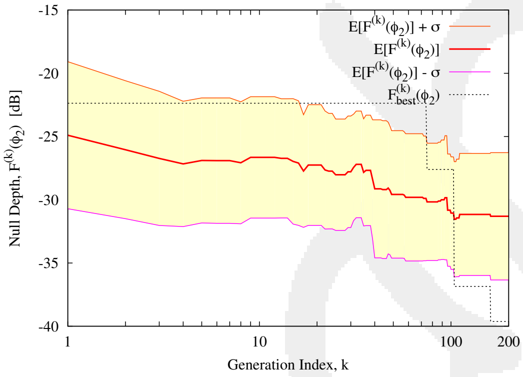

Fig.76 - Null Depth $\theta_2^i = 90°$, $\phi_2^i = 113°$ Statistics

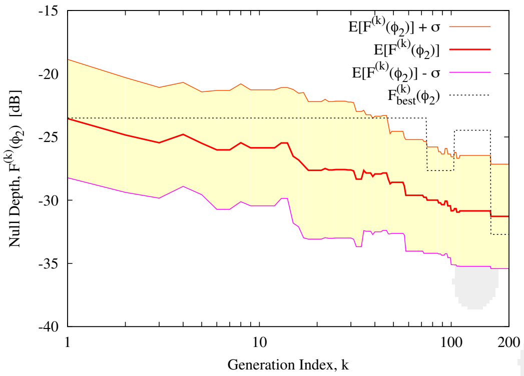

Fig.77 - Null Depth $\theta_3^i = 90°$, $\phi_3^i = 164°$ Statistics

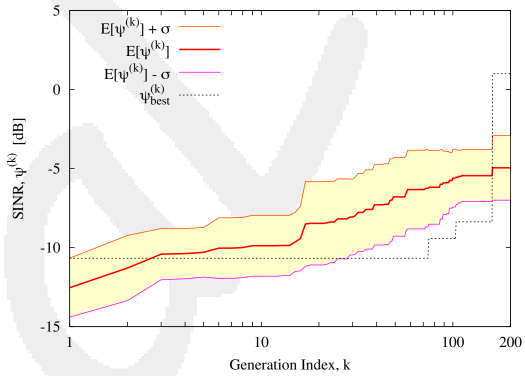

Fig.78 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$AF(\theta_2^i, \phi_2^i)$	$AF(\theta_3^i, \phi_3^i)$	*Nr. Active Elements*	$SINR\,[dB]$
GA	-38.28	-39.62	-32.70	19	1.00

Tab.14 - GA Simulation Results Analysis

TEST CASE 14 - 64 Elements - Fixed Scenario, Single Interference - $\eta \in [0.00 - 1.00]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a single interference.

Test Case Description

- Number of Elements $N = 64$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 1$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$

Optimization Approach: GA

- Number of Variables: $X = 64$ (α_n, $n = 1, ..., N$)
- Population: 32
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.00$
- Maximum Thinning Coefficient: $\eta_{max} = 1.00$
- Number of Repetitions for Statistical Analysis: 20

GA - 64 Elements - Single Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$

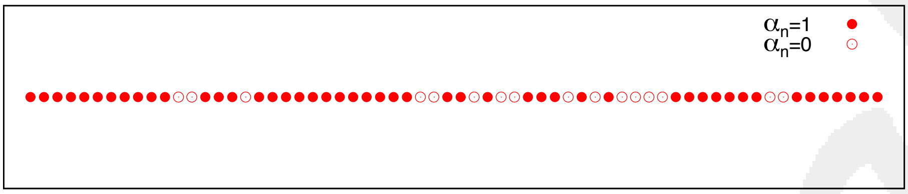

Fig.79 - Thinning Configuration

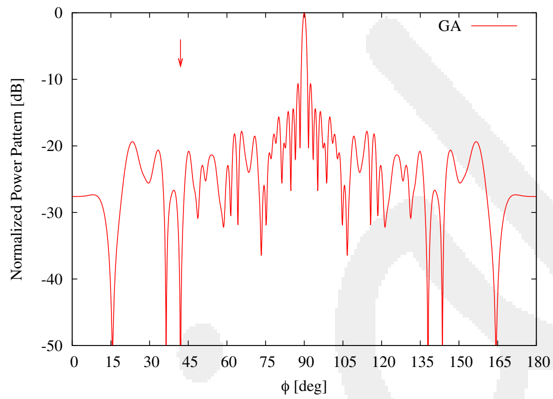

Fig.80 - Pattern

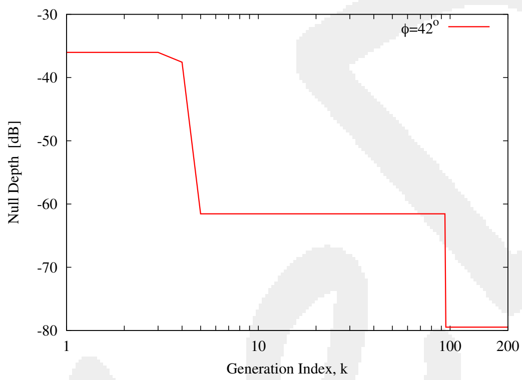

Fig.81 - Nulls Depth

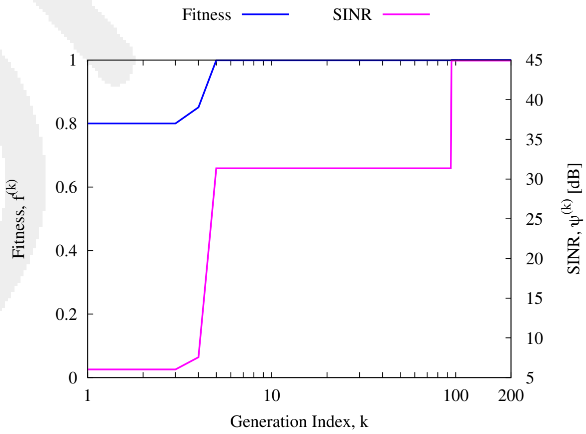

Fig.82 - Fitness - SINR

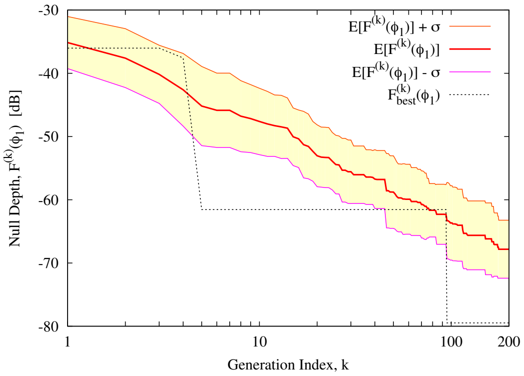

Fig.83 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

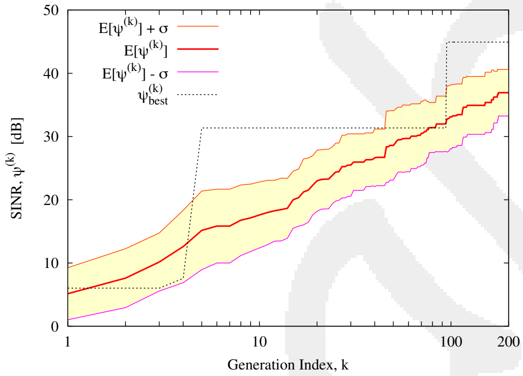

Fig.84 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$Nr. Active Elements$	$SINR\,[dB]$
GA	-79.47	48	44.93

Tab.15 - GA Simulation Results Analysis

TEST CASE 15 - 64 Elements - Fixed Scenario, Single Interference - $\eta \in [0.50 - 0.70]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a single interference.

Test Case Description

- Number of Elements $N = 64$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 1$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$

Optimization Approach: GA

- Number of Variables: $X = 64$ (α_n, $n = 1, ..., N$)
- Population: 32
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.50$
- Maximum Thinning Coefficient: $\eta_{max} = 0.70$
- Number of Repetitions for Statistical Analysis: 20

GA - 64 Elements - Single Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$

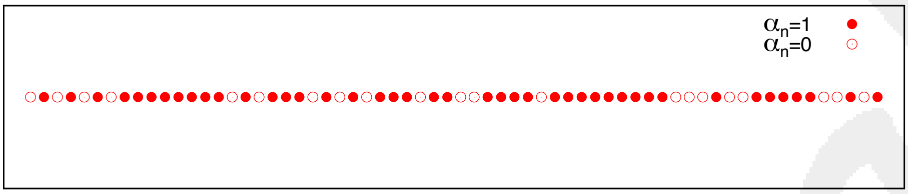

Fig.85 - Thinning Configuration

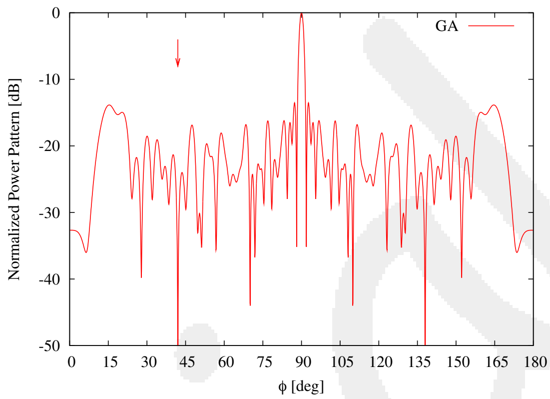

Fig.86 - Pattern

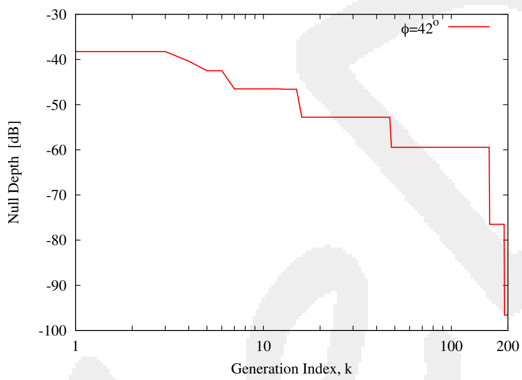

Fig.87 - Nulls Depth

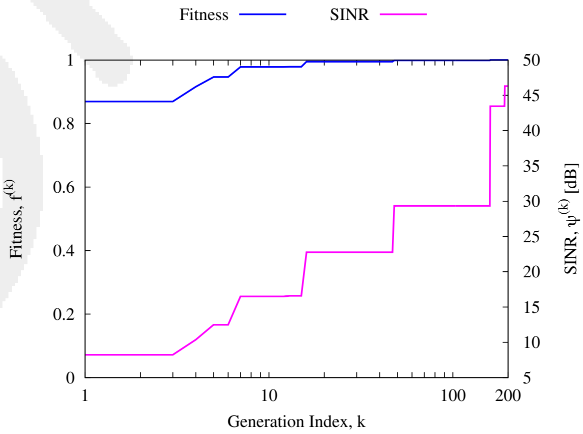

Fig.88 - Fitness - SINR

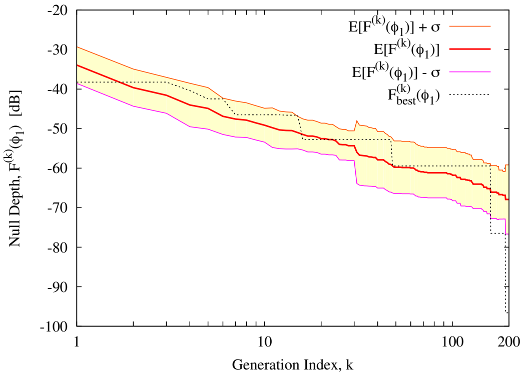

Fig.89 - NullsDepth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

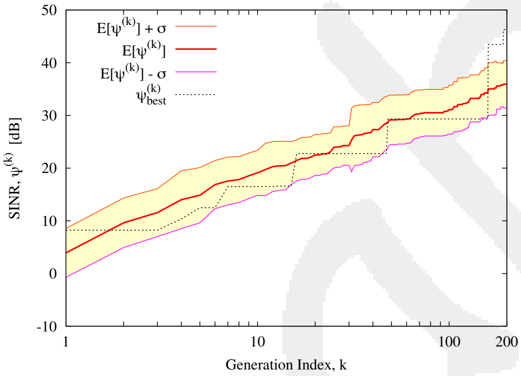

Fig.90 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$Nr.\, Active\, Elements$	$SINR\,[dB]$
GA	-96.59	43	46.29

Tab.16 - GA Simulation Results Analysis

TEST CASE 16 - 64 Elements - Fixed Scenario, Single Interference - $\eta \in [0.60 - 0.60]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a single interference.

Test Case Description

- Number of Elements $N = 64$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 1$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$

Optimization Approach: GA

- Number of Variables: $X = 64$ (α_n, $n = 1, ..., N$)
- Population: 32
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.60$
- Maximum Thinning Coefficient: $\eta_{max} = 0.60$
- Number of Repetitions for Statistical Analysis: 20

GA - 64 Elements - Single Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$

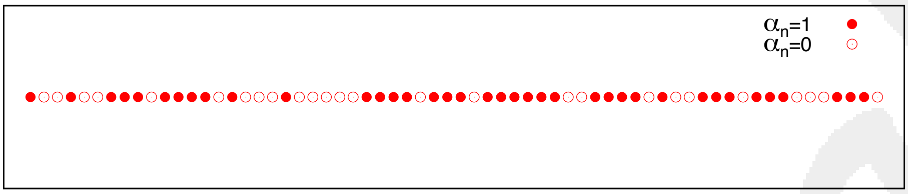

Fig.91 - Thinning Configuration

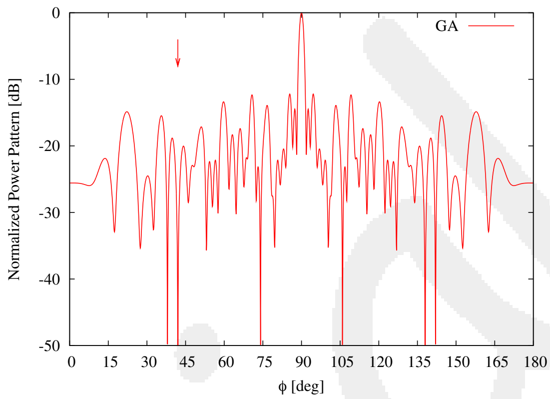

Fig.92 - Pattern

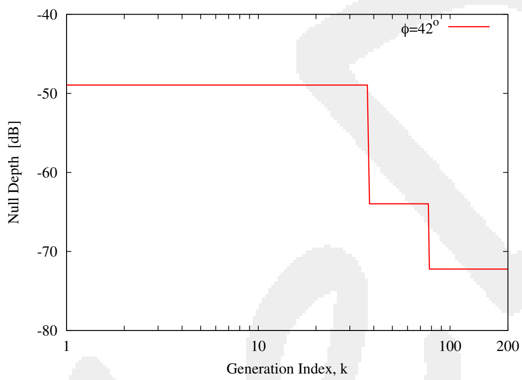

Fig.93 - Nulls Depth

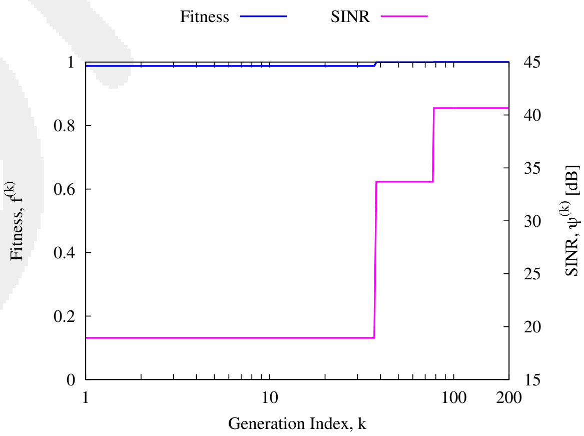

Fig.94 - Fitness - SINR

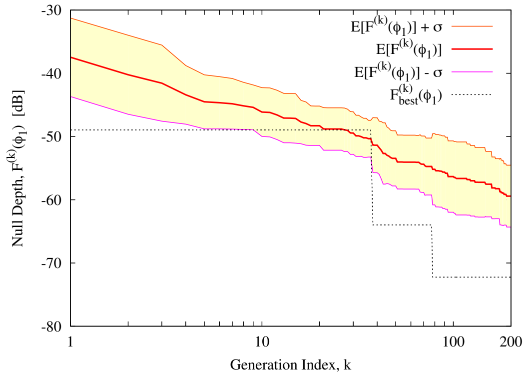

Fig.95 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

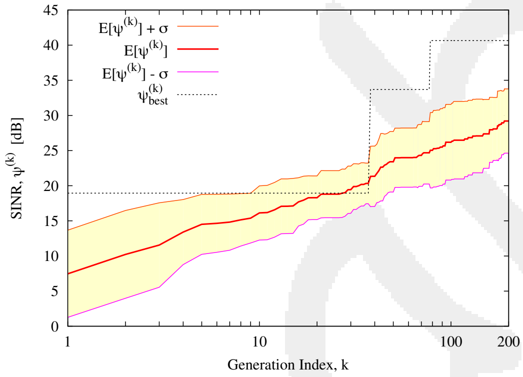

Fig.96 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$Nr. Active Elements$	$SINR\,[dB]$
GA	-72.23	38	40.65

Tab.17 - GA Simulation Results Analysis

TEST CASE 17 - 64 Elements - Fixed Scenario, Double Interference - $\eta \in [0.00 - 1.00]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a double interference.

Test Case Description

- Number of Elements $N = 64$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 2$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$

Optimization Approach: GA

- Number of Variables: $X = 64$ (α_n, $n = 1, ..., N$)
- Population: 32
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.00$
- Maximum Thinning Coefficient: $\eta_{max} = 1.00$
- Number of Repetitions for Statistical Analysis: 20

GA - 64 Elements - Double Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$

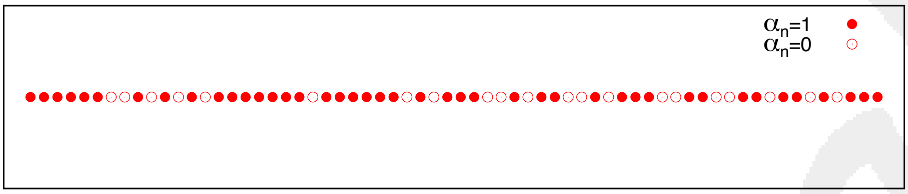

Fig.97 - Thinning Configuration

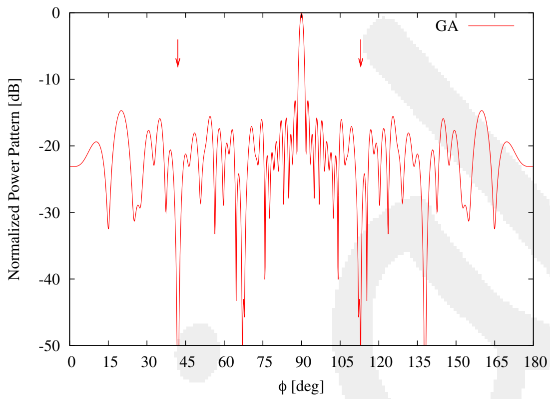

Fig.98 - Pattern

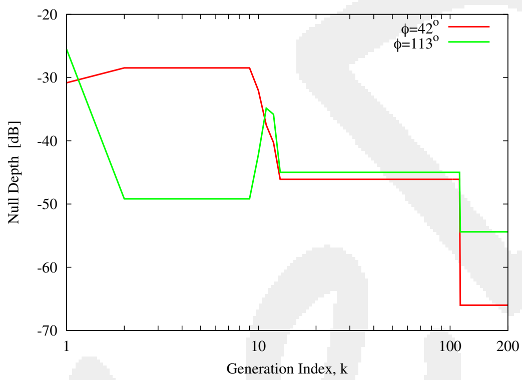

Fig.99 - Nulls Depth

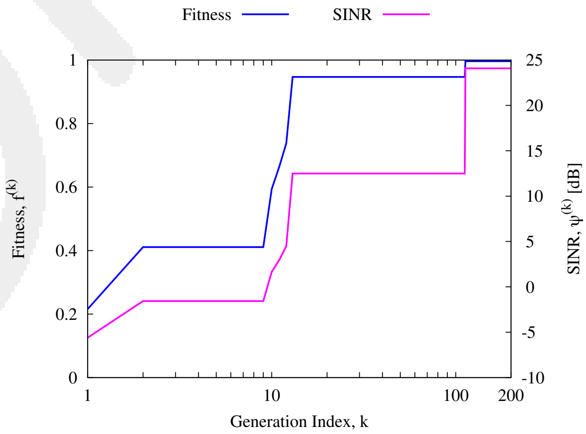

Fig.100 - Fitness - SINR

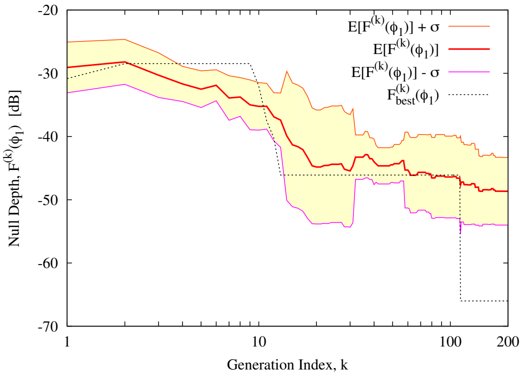

Fig.101 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

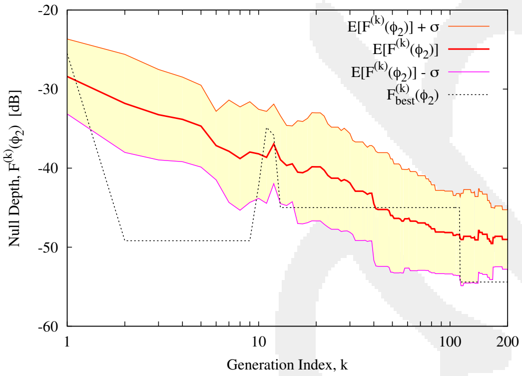

Fig.102 - Null Depth $\theta_2^i = 90°$, $\phi_2^i = 113°$ Statistics

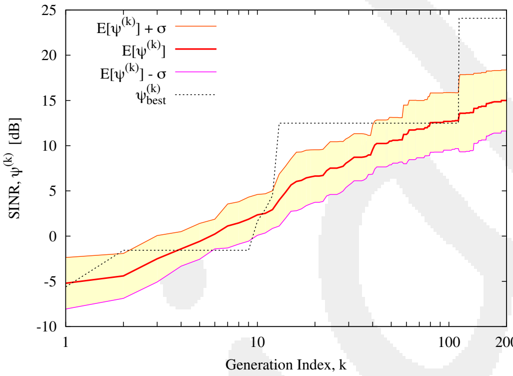

Fig.103 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$AF(\theta_2^i, \phi_2^i)$	*Nr. Active Elements*	$SINR\,[dB]$
GA	-65.99	-54.40	43	24.08

Tab.18 - GA Simulation Results Analysis

TEST CASE 18 - 64 Elements - Fixed Scenario, Double Interference - $\eta \in [0.50 - 0.70]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a double interference.

Test Case Description

- Number of Elements $N = 64$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 2$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$

Optimization Approach: GA

- Number of Variables: $X = 64$ (α_n, $n = 1, ..., N$)
- Population: 32
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.50$
- Maximum Thinning Coefficient: $\eta_{max} = 0.70$
- Number of Repetitions for Statistical Analysis: 20

GA - 64 Elements - Double Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$

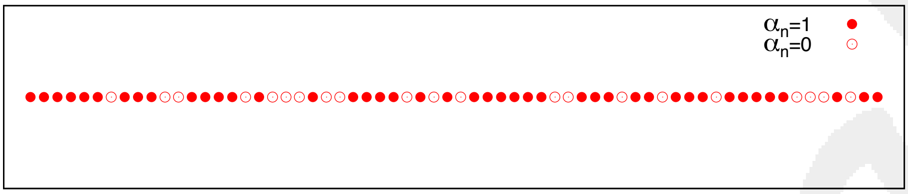

Fig.104 - Thinning Configuration

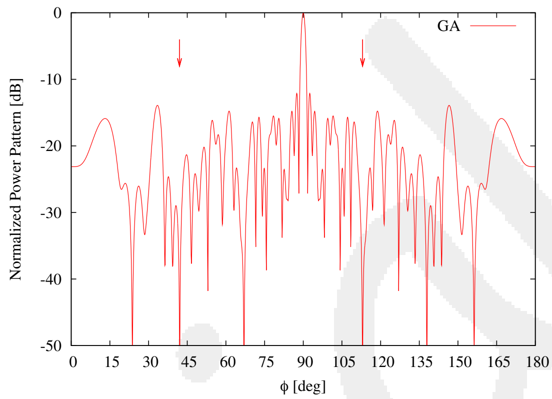

Fig.105 - Pattern

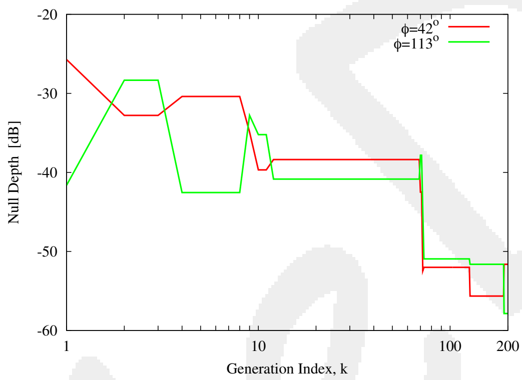

Fig.106 - Nulls Depth

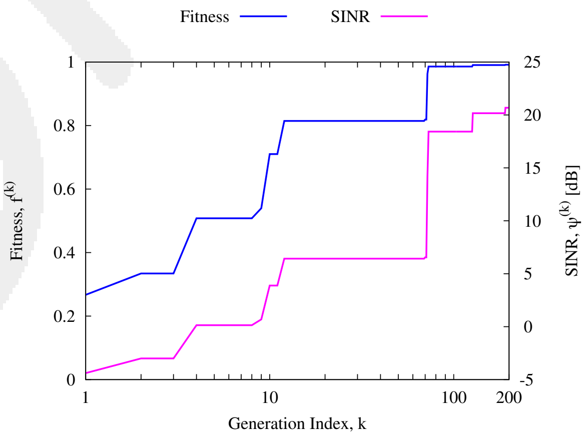

Fig.107 - Fitness - SINR

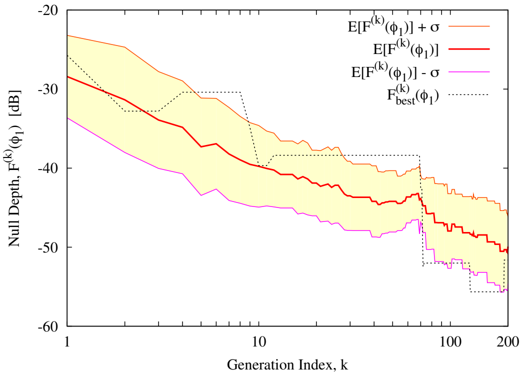

Fig.108 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

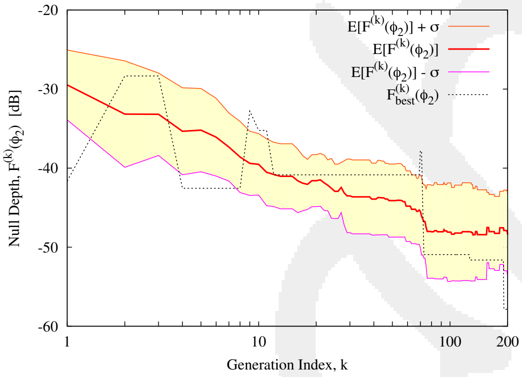

Fig.109 - Null Depth $\theta_2^i = 90°$, $\phi_2^i = 113°$ Statistics

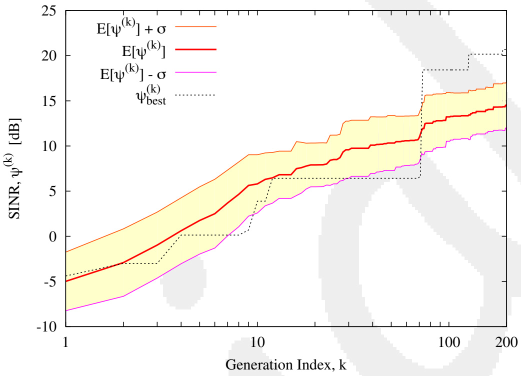

Fig.110 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$AF(\theta_2^i, \phi_2^i)$	$Nr. Active\ Elements$	$SINR\,[dB]$
GA	-51.62	-57.86	43	20.68

Tab.19 - GA Simulation Results Analysis

TEST CASE 19 - 64 Elements - Fixed Scenario, Double Interference - $\eta \in [0.60 - 0.60]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a double interference.

Test Case Description

- Number of Elements $N = 64$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 2$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$

Optimization Approach: GA

- Number of Variables: $X = 64$ (α_n, $n = 1, ..., N$)
- Population: 32
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.60$
- Maximum Thinning Coefficient: $\eta_{max} = 0.60$
- Number of Repetitions for Statistical Analysis: 20

GA - 64 Elements - Double Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$

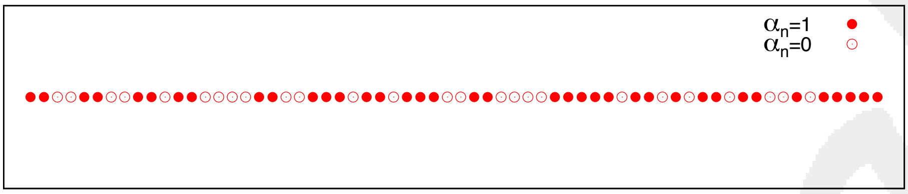

Fig.111 - Thinning Configuration

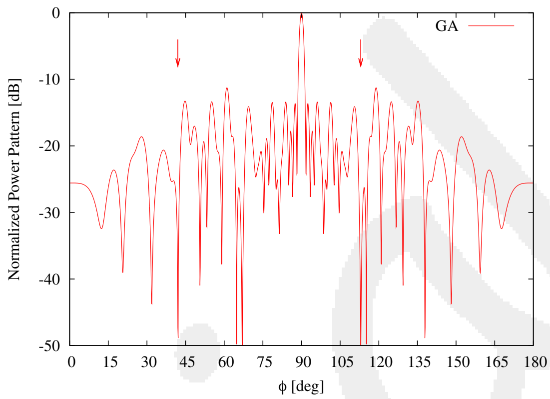

Fig.112 - Pattern

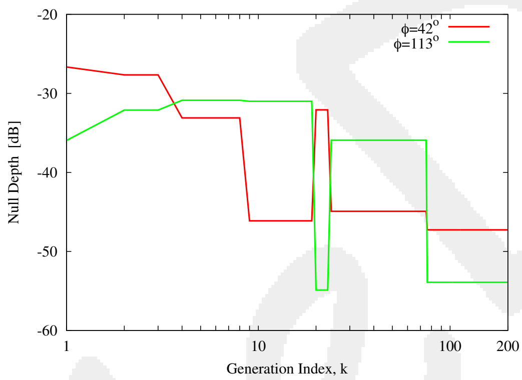

Fig.113 - Nulls Depth

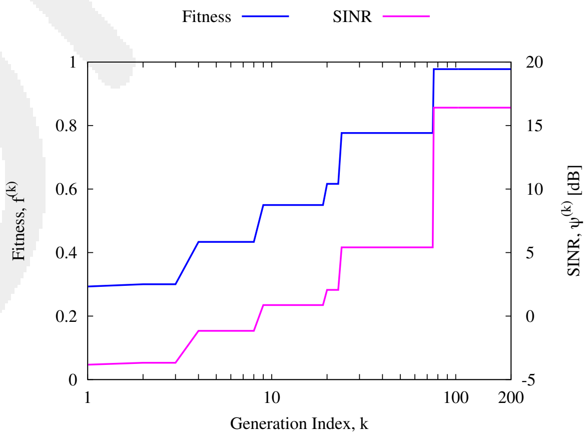

Fig.114 - Fitness - SINR

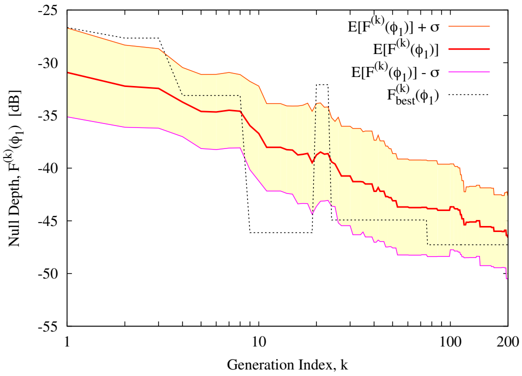

Fig.115 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

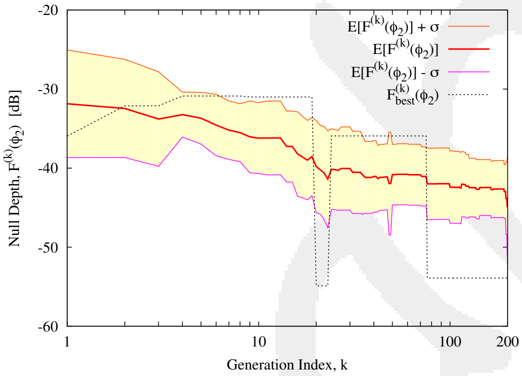

Fig.116 - Null Depth $\theta_2^i = 90°$, $\phi_2^i = 113°$ Statistics

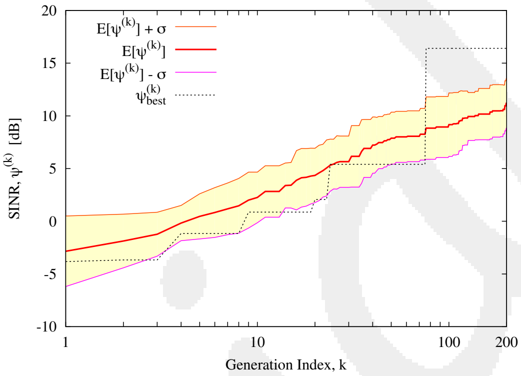

Fig.117 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$AF(\theta_2^i, \phi_2^i)$	*Nr. Active Elements*	$SINR\,[dB]$
GA	-47.27	-53.90	38	16.41

Tab.20 - GA Simulation Results Analysis

TEST CASE 20 - 64 Elements - Fixed Scenario, Triple Interference - $\eta \in [0.00 - 1.00]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a double interference.

Test Case Description

- Number of Elements $N = 64$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 3$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$, $\theta_3^i = 90°$, $\phi_3^i = 164°$

Optimization Approach: GA

- Number of Variables: $X = 64$ (α_n, $n = 1, ..., N$)
- Population: 32
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.00$
- Maximum Thinning Coefficient: $\eta_{max} = 1.00$
- Number of Repetitions for Statistical Analysis: 20

GA - 64 Elements - Triple Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$, $\theta_3^i = 90°$, $\phi_3^i = 164°$

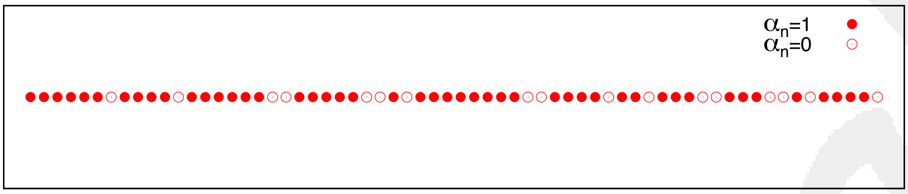

Fig.118 - Thinning Configuration

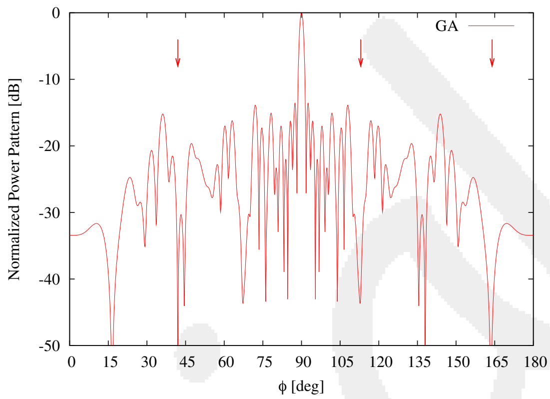

Fig.119 - Pattern

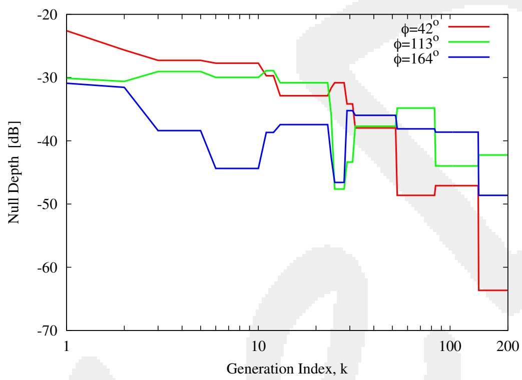

Fig.120 - Nulls Depth

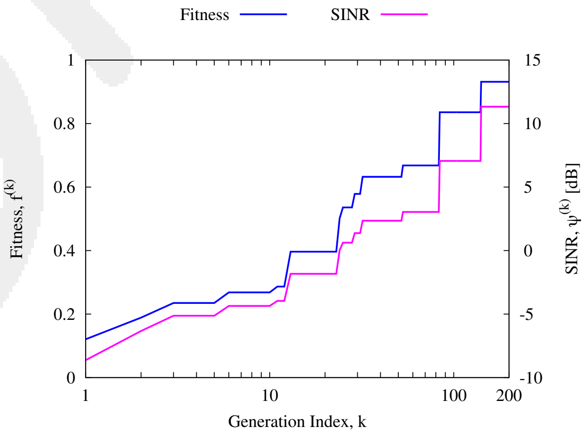

Fig.121 - Fitness - SINR

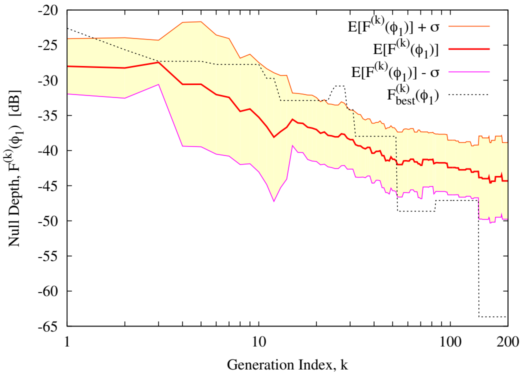

Fig.122 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

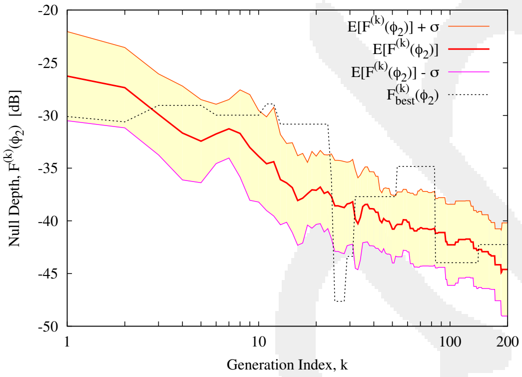

Fig.123 - Null Depth $\theta_2^i = 90°$, $\phi_2^i = 113°$ Statistics

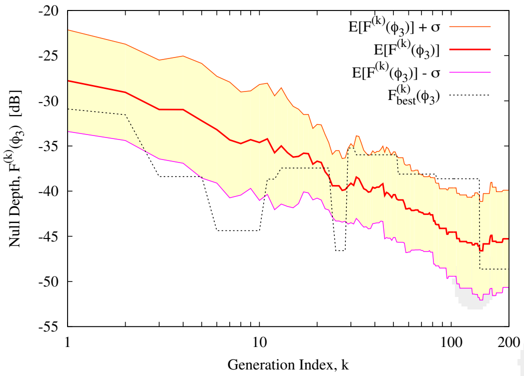

Fig.124 - Null Depth $\theta_3^i = 90°$, $\phi_3^i = 164°$ Statistics

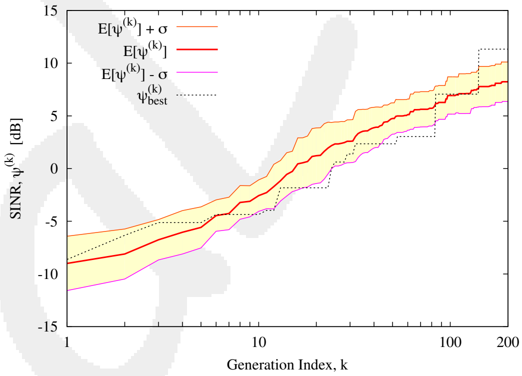

Fig.125 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$AF(\theta_2^i, \phi_2^i)$	$AF(\theta_3^i, \phi_3^i)$	$Nr. Active Elements$	$SINR\,[dB]$
GA	-63.65	-42.25	-48.63	47	11.33

Tab.21 - GA Simulation Results Analysis

TEST CASE 21 - 64 Elements - Fixed Scenario, Triple Interference - $\eta \in [0.50 - 0.70]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a double interference.

Test Case Description

- Number of Elements $N = 64$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 3$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$, $\theta_3^i = 90°$, $\phi_3^i = 164°$

Optimization Approach: GA

- Number of Variables: $X = 64$ (α_n, $n = 1, ..., N$)
- Population: 32
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.50$
- Maximum Thinning Coefficient: $\eta_{max} = 0.70$
- Number of Repetitions for Statistical Analysis: 20

GA - 64 Elements - Triple Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$, $\theta_3^i = 90°$, $\phi_3^i = 164°$

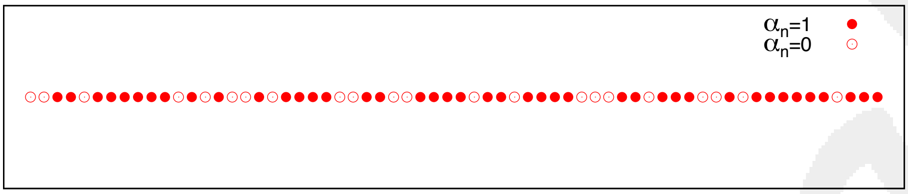

Fig.126 - Thinning Configuration

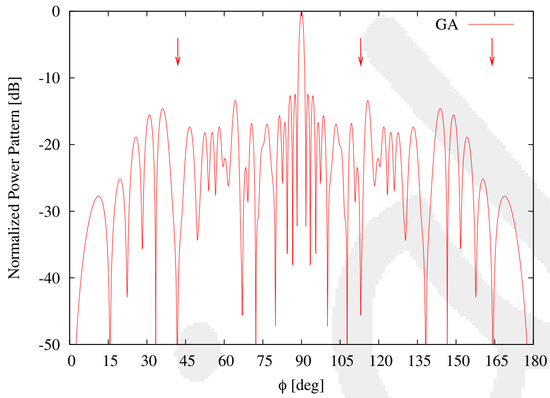

Fig.127 - Pattern

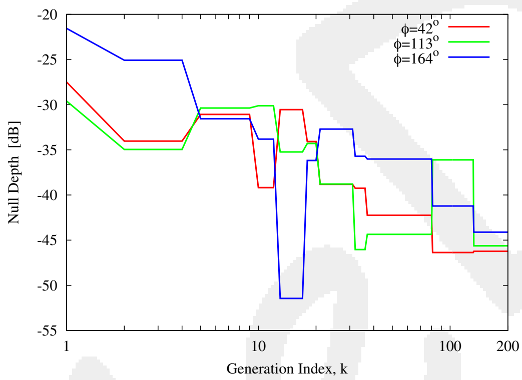

Fig.128 - Nulls Depth

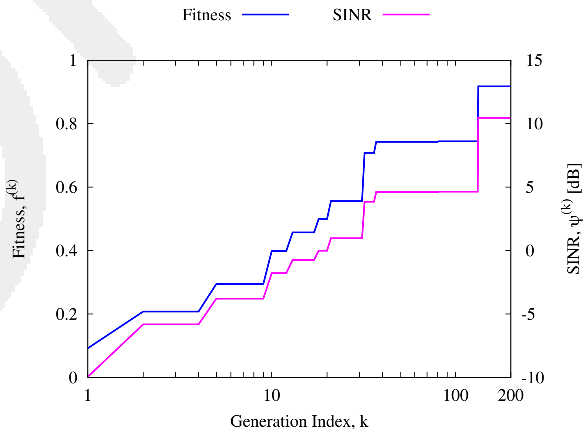

Fig.129 - Fitness - SINR

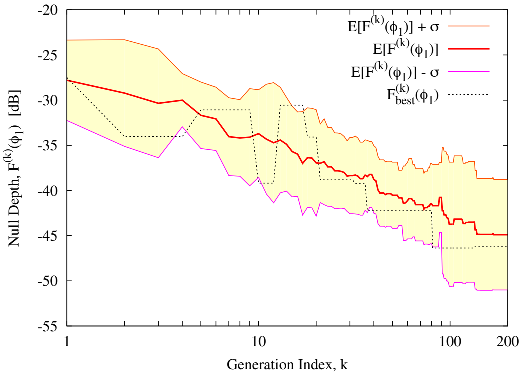

Fig.130 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

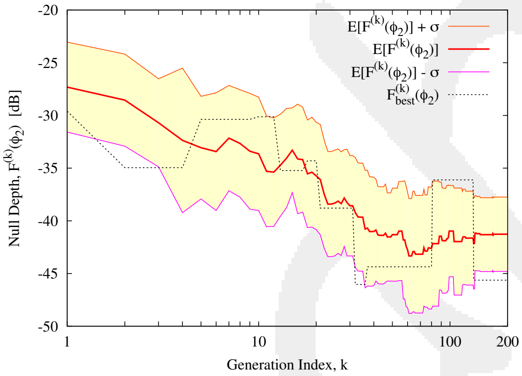

Fig.131 - Null Depth $\theta_2^i = 90°$, $\phi_2^i = 113°$ Statistics

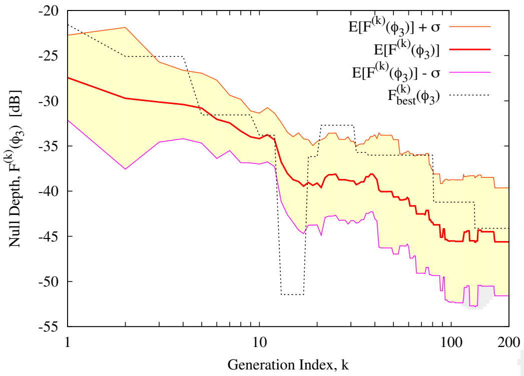

Fig.132 - Null Depth $\theta_3^i = 90°$, $\phi_3^i = 164°$ Statistics

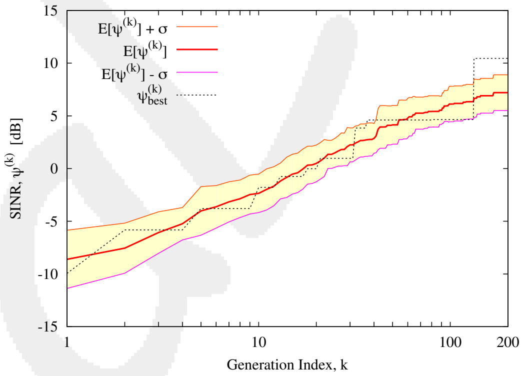

Fig.133 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$AF(\theta_2^i, \phi_2^i)$	$AF(\theta_3^i, \phi_3^i)$	*Nr. Active Elements*	$SINR\,[dB]$
GA	-46.23	-45.63	-44.12	42	10.46

Tab.22 - GA Simulation Results Analysis

TEST CASE 22 - 64 Elements - Fixed Scenario, Triple Interference - $\eta \in [0.60 - 0.60]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a triple interference.

Test Case Description

- Number of Elements $N = 64$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 3$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$, $\theta_3^i = 90°$, $\phi_3^i = 164°$

Optimization Approach: GA

- Number of Variables: $X = 64$ (α_n, $n = 1, ..., N$)
- Population: 32
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.60$
- Maximum Thinning Coefficient: $\eta_{max} = 0.60$
- Number of Repetitions for Statistical Analysis: 20

GA - 64 Elements - Triple Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$, $\theta_3^i = 90°$, $\phi_3^i = 164°$

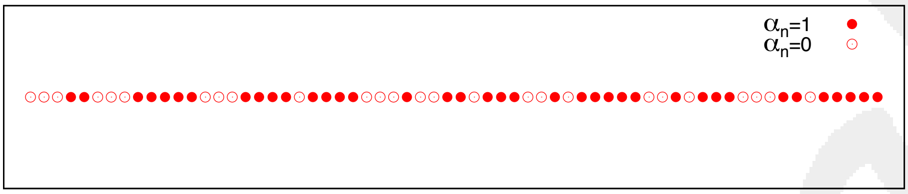

Fig.134 - Thinning Configuration

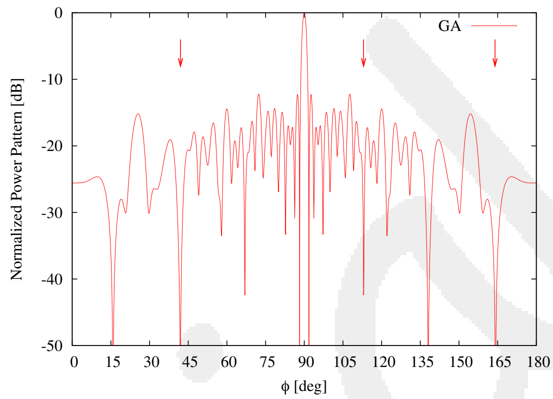

Fig.135 - Pattern

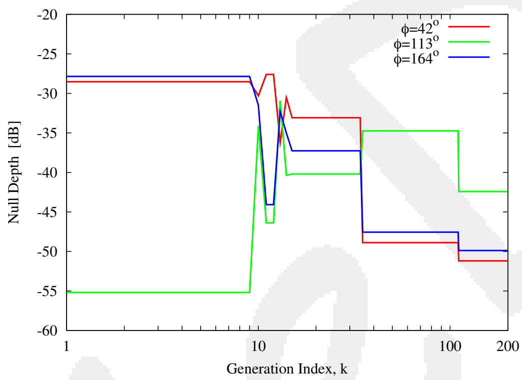

Fig.136 - Nulls Depth

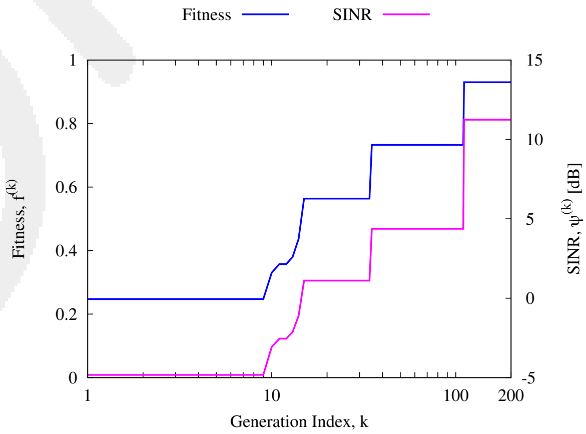

Fig.137 - Fitness - SINR

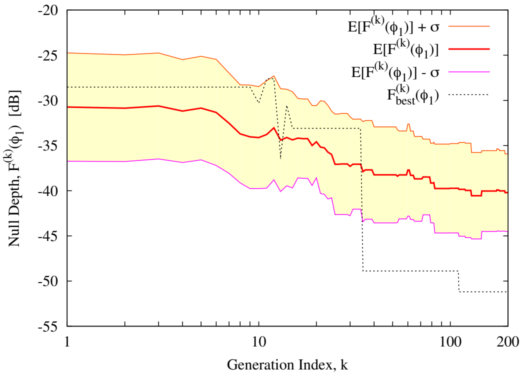

Fig.138 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

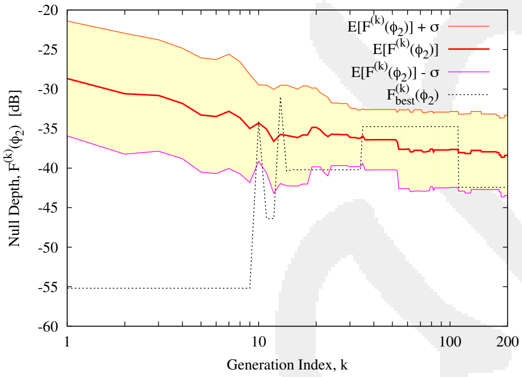

Fig.139 - Null Depth $\theta_2^i = 90°$, $\phi_2^i = 113°$ Statistics

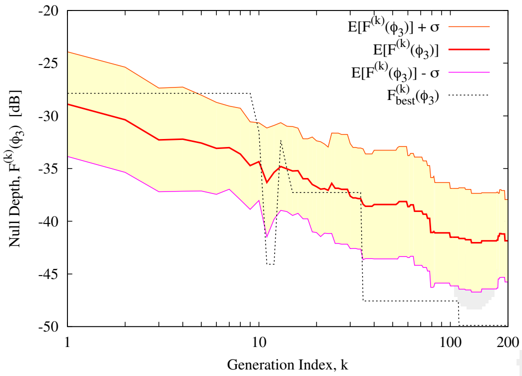

Fig.140 - Null Depth $\theta_3^i = 90°$, $\phi_3^i = 164°$ Statistics

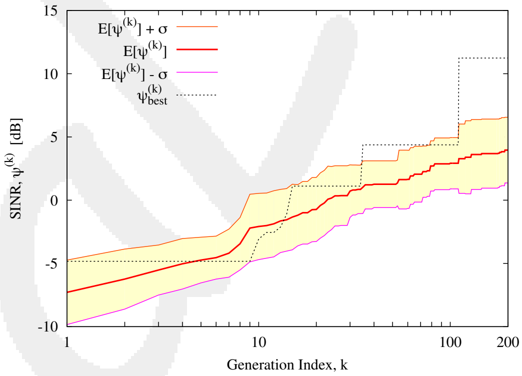

Fig.141 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$AF(\theta_2^i, \phi_2^i)$	$AF(\theta_3^i, \phi_3^i)$	$Nr. Active\ Elements$	$SINR\,[dB]$
GA	-51.19	-42.42	-49.88	38	11.24

Tab.23 - GA Simulation Results Analysis

TEST CASE 23 - 128 Elements - Fixed Scenario, Single Interference - $\eta \in [0.00 - 1.00]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a single interference.

Test Case Description

- Number of Elements $N = 128$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 1$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$

Optimization Approach: GA

- Number of Variables: $X = 128$ (α_n, $n = 1, ..., N$)
- Population: 64
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.00$
- Maximum Thinning Coefficient: $\eta_{max} = 1.00$
- Number of Repetitions for Statistical Analysis: 20

GA - 128 Elements - Single Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$

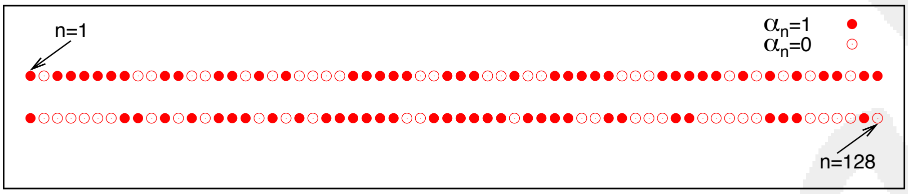

Fig.142 - Thinning Configuration

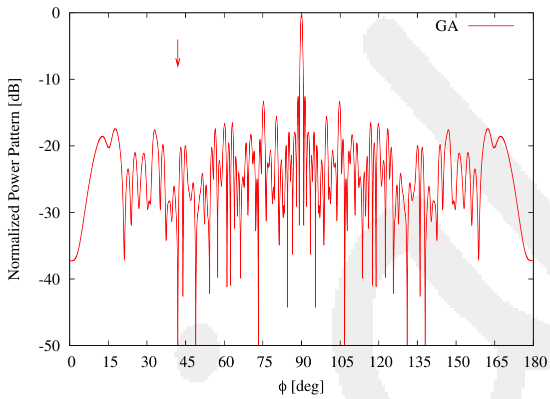

Fig.143 - Pattern

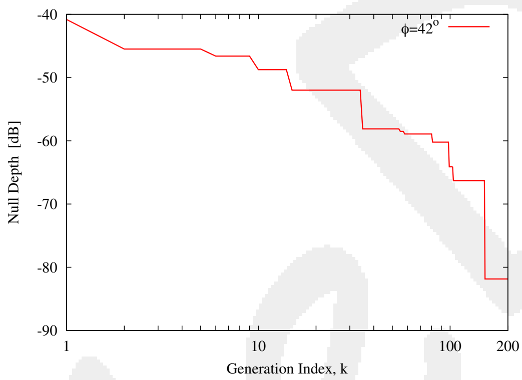

Fig.144 - Nulls Depth

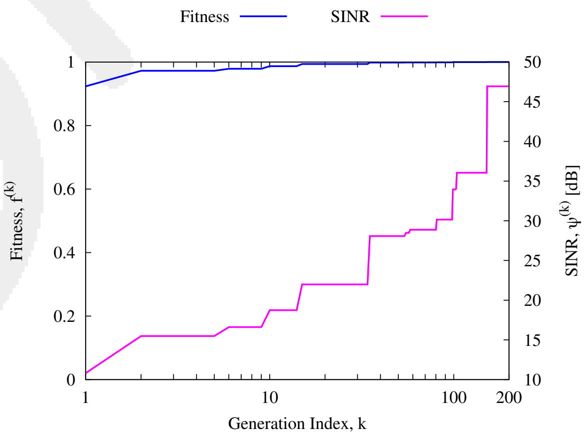

Fig.145 - Fitness - SINR

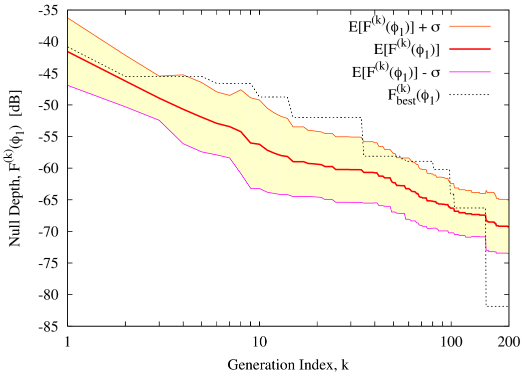

Fig.146 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

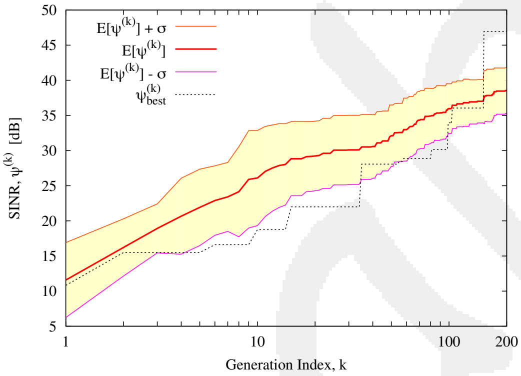

Fig.147 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$Nr.\,Active\,Elements$	$SINR\,[dB]$
GA	-81.85	73	46.94

Tab.24 - GA Simulation Results Analysis

TEST CASE 23 - 128 Elements - Fixed Scenario, Single Interference - $\eta \in [0.50 - 0.70]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a single interference.

Test Case Description

- Number of Elements $N = 128$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 1$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$

Optimization Approach: GA

- Number of Variables: $X = 128$ (α_n, $n = 1, ..., N$)
- Population: 64
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.50$
- Maximum Thinning Coefficient: $\eta_{max} = 0.70$
- Number of Repetitions for Statistical Analysis: 20

GA - 128 Elements - Single Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$

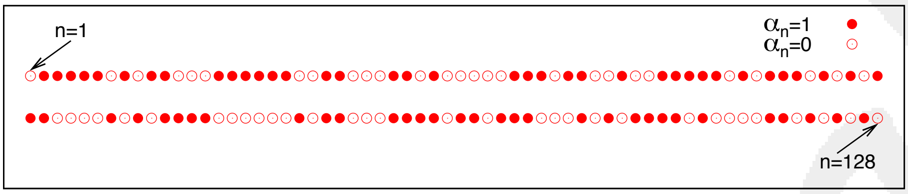

Fig.148 - Thinning Configuration

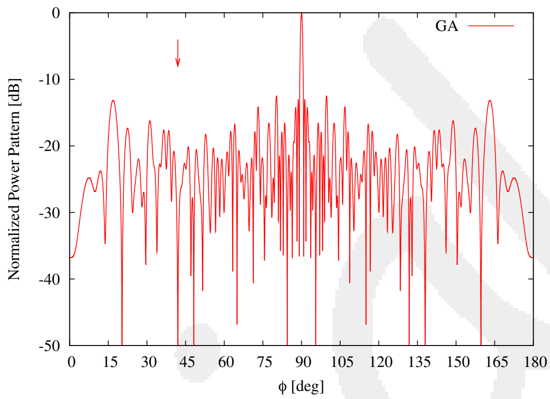

Fig.149 - Pattern

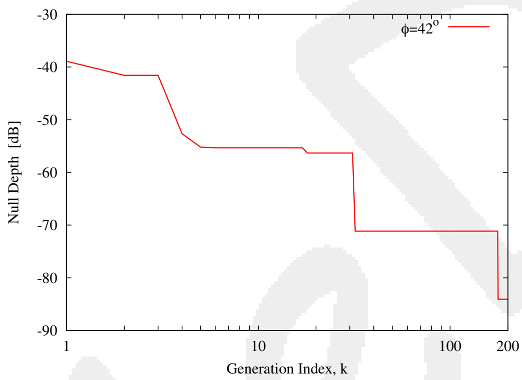

Fig.150 - Nulls Depth

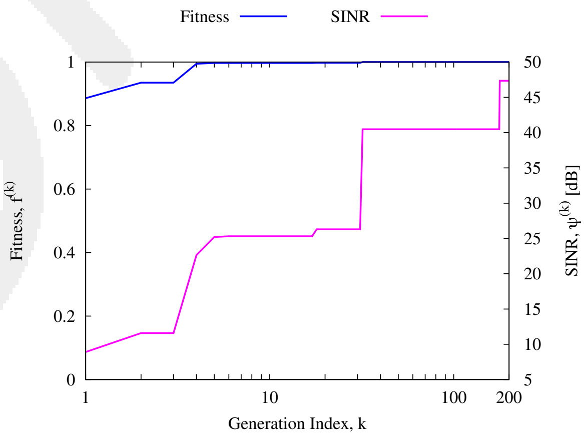

Fig.151 - Fitness - SINR

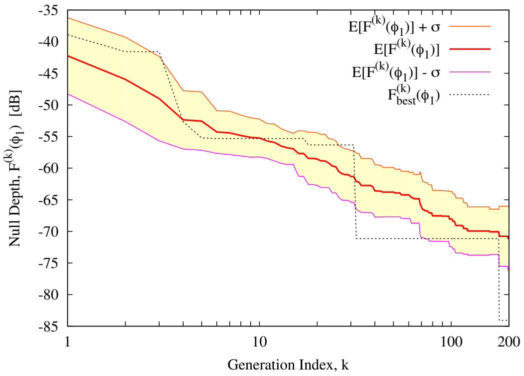

Fig.152 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

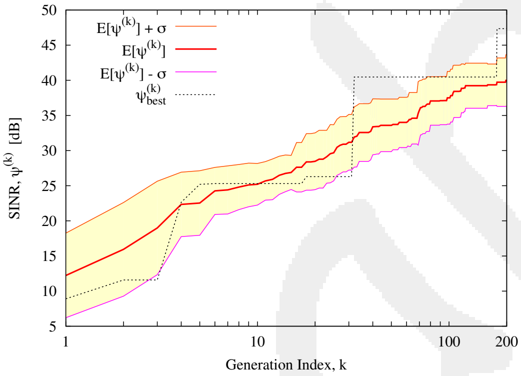

Fig.153 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$Nr. Active\ Elements$	$SINR\,[dB]$
GA	-84.07	69	47.35

Tab.25 - GA Simulation Results Analysis

TEST CASE 10 - 128 Elements - Fixed Scenario, Single Interference - $\eta \in [0.60 - 0.60]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a single interference.

Test Case Description

- Number of Elements $N = 128$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 1$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$

Optimization Approach: GA

- Number of Variables: $X = 128$ (α_n, $n = 1, ..., N$)
- Population: 64
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.60$
- Maximum Thinning Coefficient: $\eta_{max} = 0.60$
- Number of Repetitions for Statistical Analysis: 20

GA - 128 Elements - Single Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$

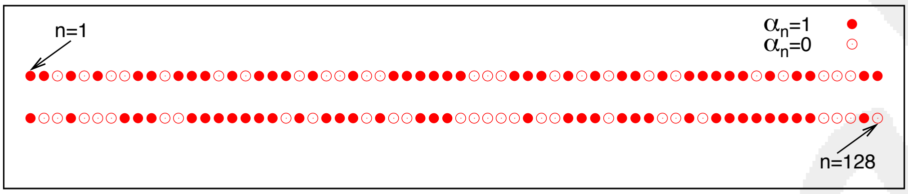

Fig.154 - Thinning Configuration

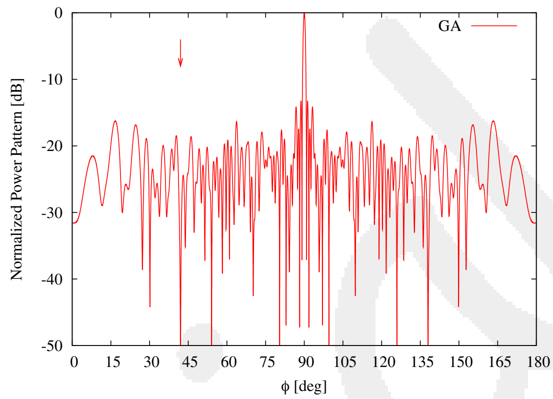

Fig.155 - Pattern

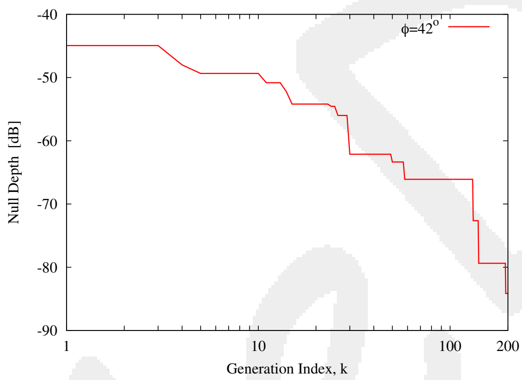

Fig.156 - Nulls Depth

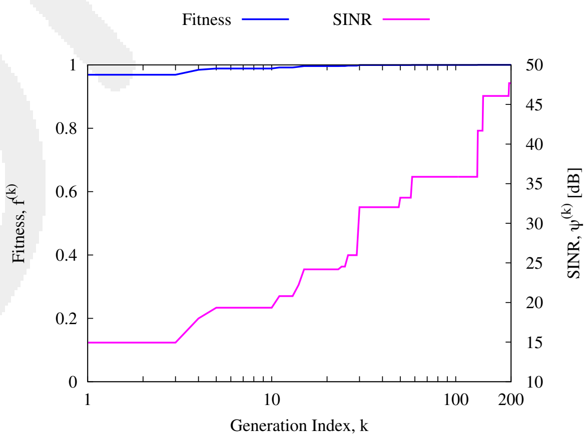

Fig.157 - Fitness - SINR

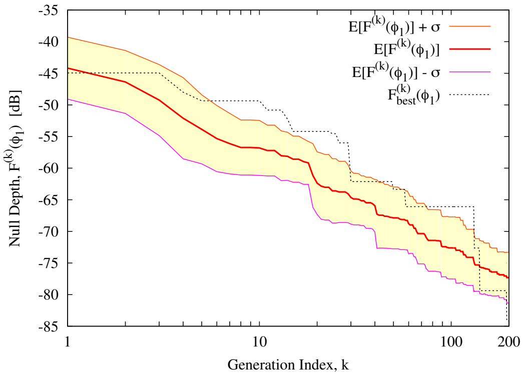

Fig.158 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

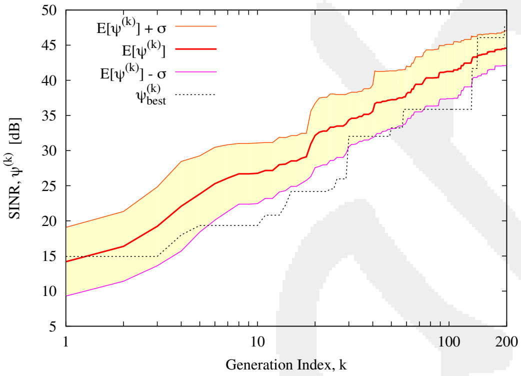

Fig.159 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$Nr. Active\ Elements$	$SINR\,[dB]$
GA	-84.14	76	47.69

Tab.26 - GA Simulation Results Analysis

TEST CASE 23 - 128 Elements - Fixed Scenario, Double Interference - $\eta \in [0.00 - 1.00]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a double interference.

Test Case Description

- Number of Elements $N = 128$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 2$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$

Optimization Approach: GA

- Number of Variables: $X = 128$ (α_n, $n = 1, ..., N$)
- Population: 64
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.00$
- Maximum Thinning Coefficient: $\eta_{max} = 1.00$
- Number of Repetitions for Statistical Analysis: 20

GA - 128 Elements - Double Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$

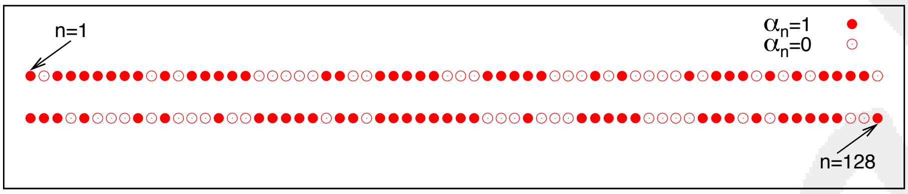

Fig.160 - Thinning Configuration

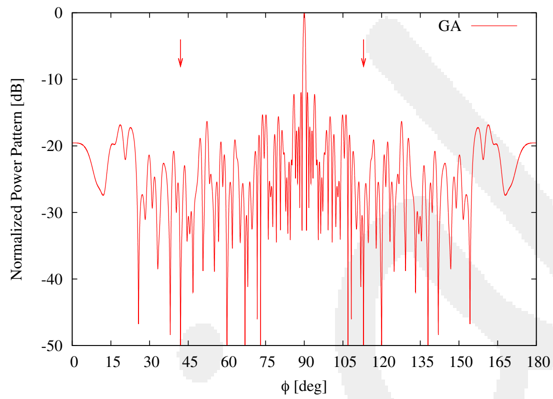

Fig.161 - Pattern

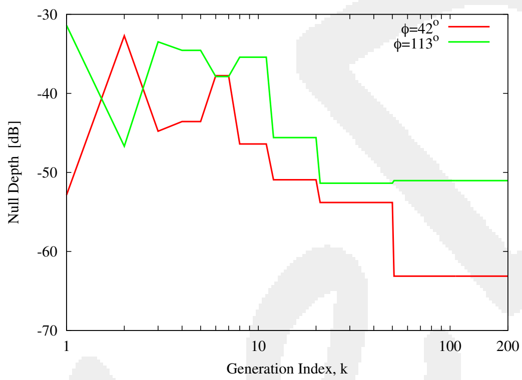

Fig.162 - Nulls Depth

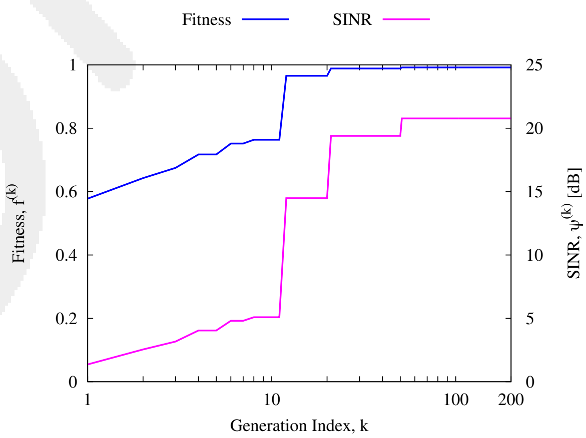

Fig.163 - Fitness - SINR

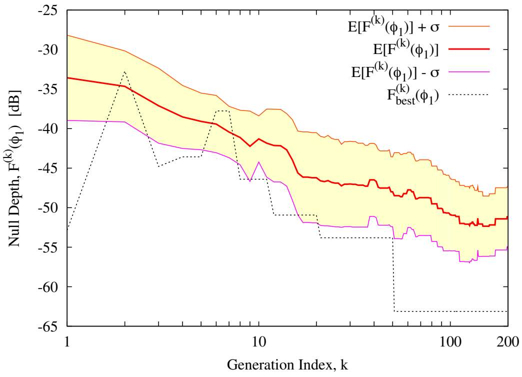

Fig.164 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

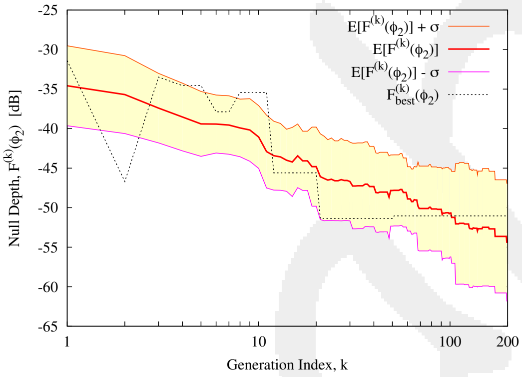

Fig.165 - Null Depth $\theta_2^i = 90°$, $\phi_2^i = 113°$ Statistics

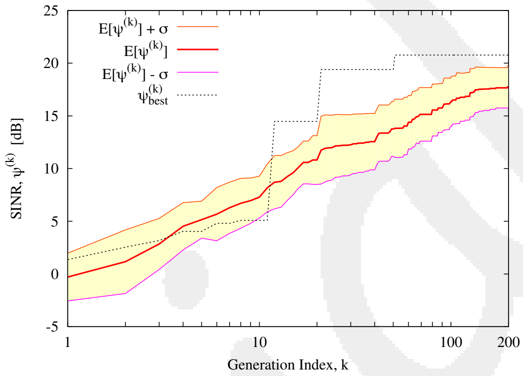

Fig.166 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$AF(\theta_2^i, \phi_2^i)$	*Nr. Active Elements*	$SINR\,[dB]$
GA	-63.12	-51.04	76	20.77

Tab.27 - GA Simulation Results Analysis

TEST CASE 23 - 128 Elements - Fixed Scenario, Double Interference - $\eta \in [0.50 - 0.70]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a double interference.

Test Case Description

- Number of Elements $N = 128$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 2$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$

Optimization Approach: GA

- Number of Variables: $X = 128$ (α_n, $n = 1, ..., N$)
- Population: 64
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.50$
- Maximum Thinning Coefficient: $\eta_{max} = 0.70$
- Number of Repetitions for Statistical Analysis: 20

GA - 128 Elements - Double Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$

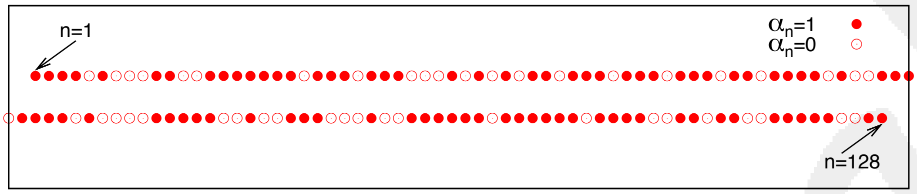

Fig.167 - Thinning Configuration

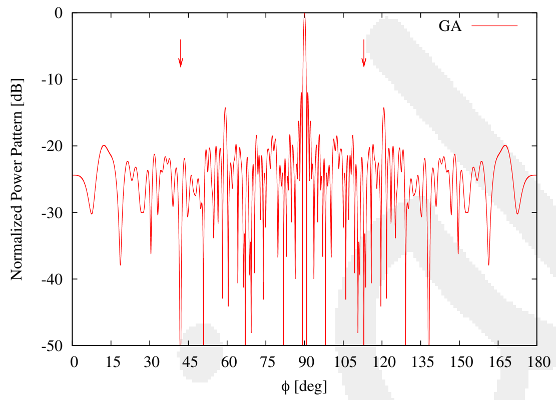

Fig.168 - Pattern

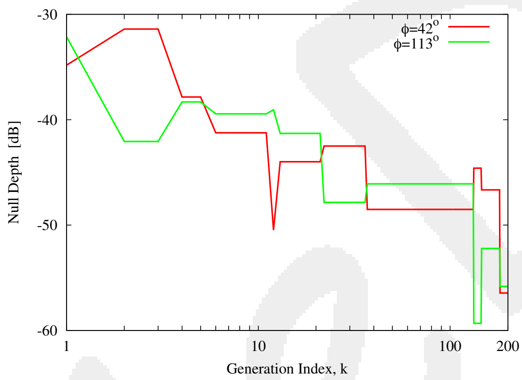

Fig.169 - Nulls Depth

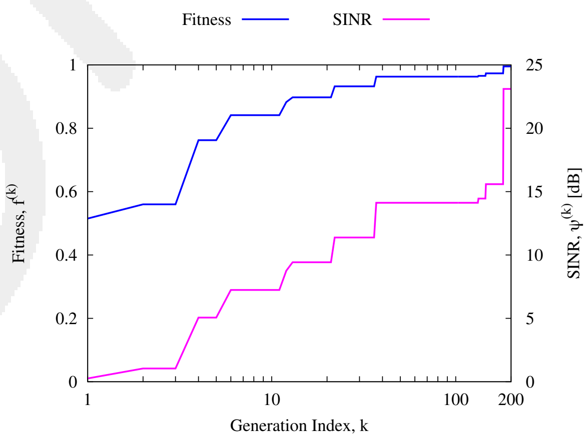

Fig.170 - Fitness - SINR

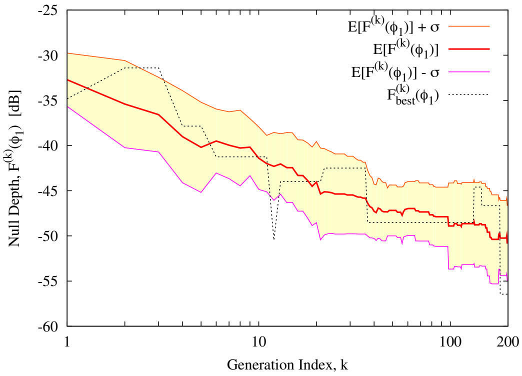

Fig.171 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

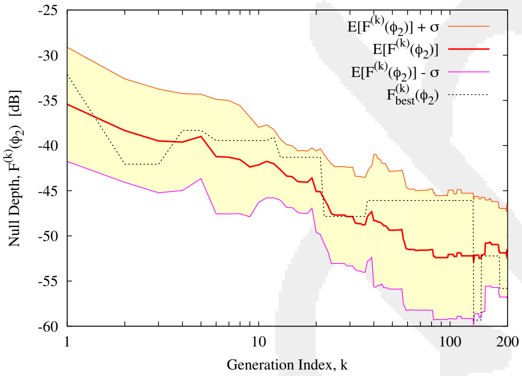

Fig.172 - Null Depth $\theta_2^i = 90°$, $\phi_2^i = 113°$ Statistics

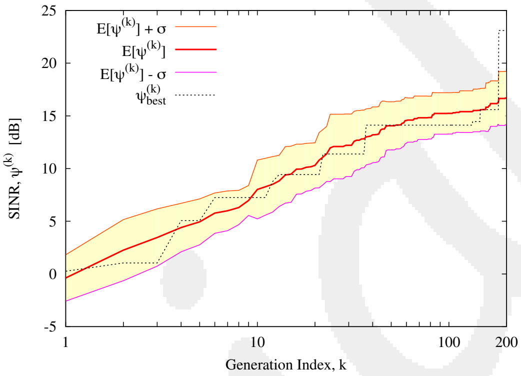

Fig.173 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$AF(\theta_2^i, \phi_2^i)$	*Nr. Active Elements*	$SINR\,[dB]$
GA	-56.45	-55.82	83	23.10

Tab.28 - GA Simulation Results Analysis

TEST CASE 10 - 128 Elements - Fixed Scenario, Double Interference - $\eta \in [0.60 - 0.60]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a double interference.

Test Case Description

- Number of Elements $N = 128$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 2$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$

Optimization Approach: GA

- Number of Variables: $X = 128$ (α_n, $n = 1, ..., N$)
- Population: 64
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.60$
- Maximum Thinning Coefficient: $\eta_{max} = 0.60$
- Number of Repetitions for Statistical Analysis: 20

GA - 128 Elements - Double Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$

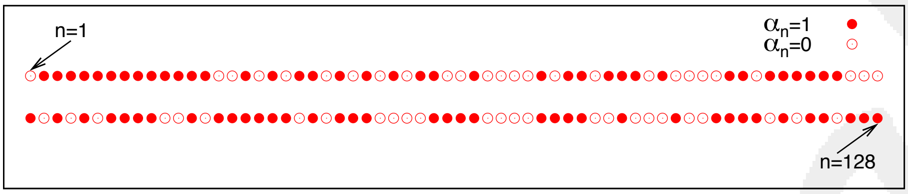

Fig.174 - Thinning Configuration

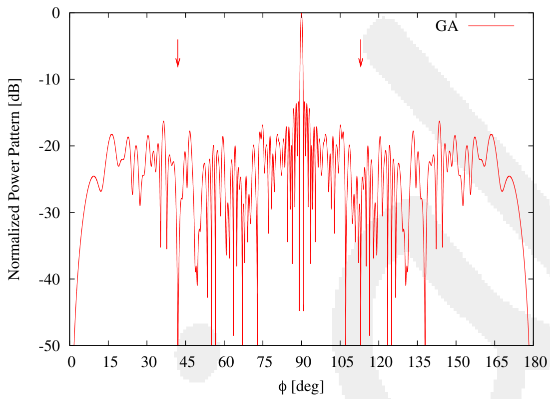

Fig.175 - Pattern

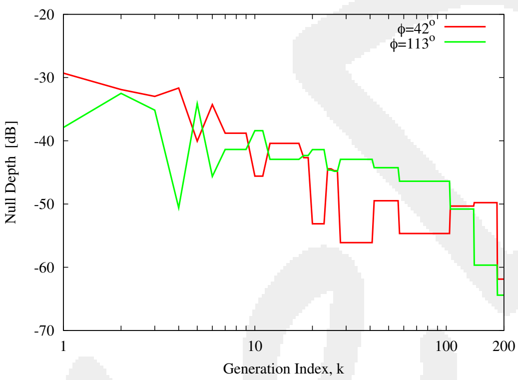

Fig.176 - Nulls Depth

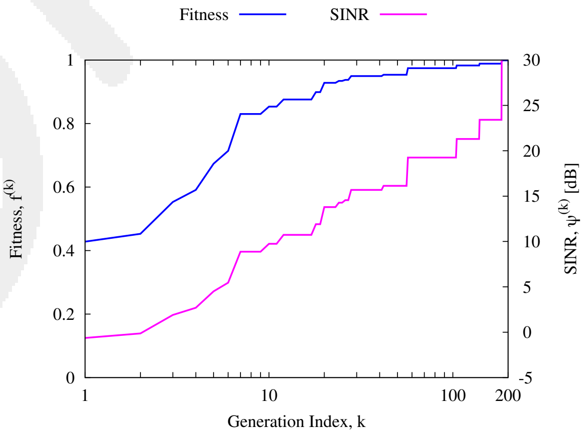

Fig.177 - Fitness - SINR

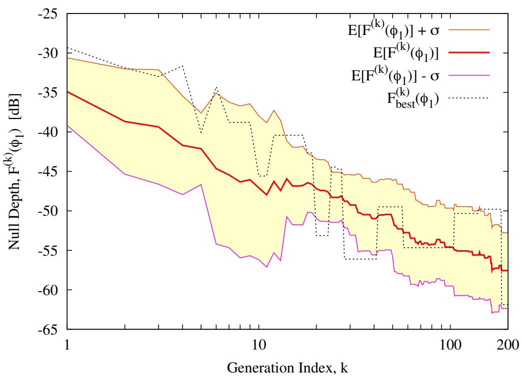

Fig.178 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

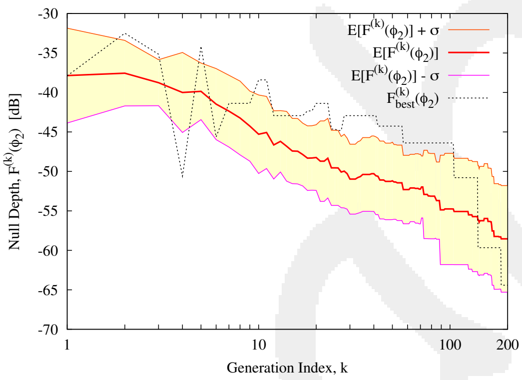

Fig.179 - Null Depth $\theta_2^i = 90°$, $\phi_2^i = 113°$ Statistics

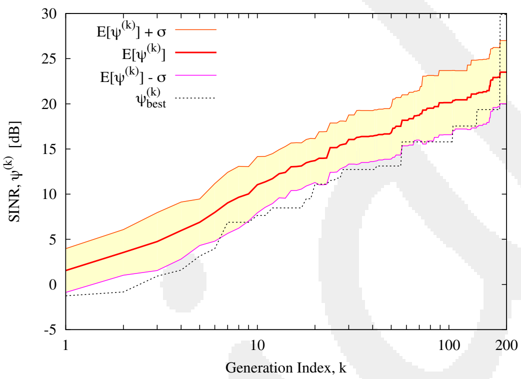

Fig.180 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$AF(\theta_2^i, \phi_2^i)$	*Nr. Active Elements*	$SINR\,[dB]$
GA	-61.87	-64.42	76	29.84

Tab.29 - GA Simulation Results Analysis

TEST CASE 23 - 128 Elements - Fixed Scenario, Triple Interference - $\eta \in [0.00 - 1.00]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a triple interference.

Test Case Description

- Number of Elements $N = 128$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 3$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$, $\theta_3^i = 90°$, $\phi_3^i = 164°$

Optimization Approach: GA

- Number of Variables: $X = 128$ (α_n, $n = 1, ..., N$)
- Population: 64
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.00$
- Maximum Thinning Coefficient: $\eta_{max} = 1.00$
- Number of Repetitions for Statistical Analysis: 20

GA - 128 Elements - Triple Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$, $\theta_3^i = 90°$, $\phi_3^i = 164°$

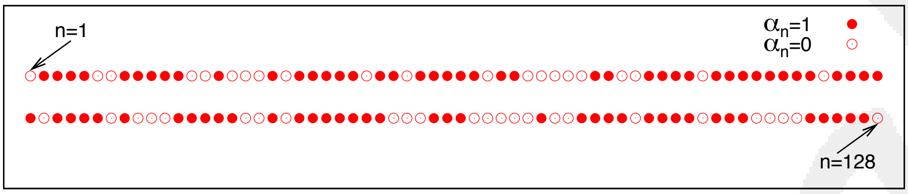

Fig.181 - Thinning Configuration

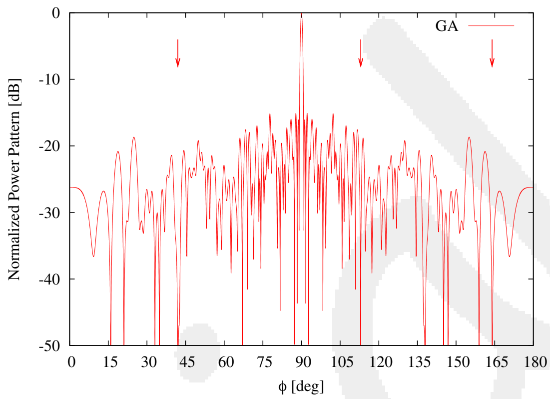

Fig.182 - Pattern

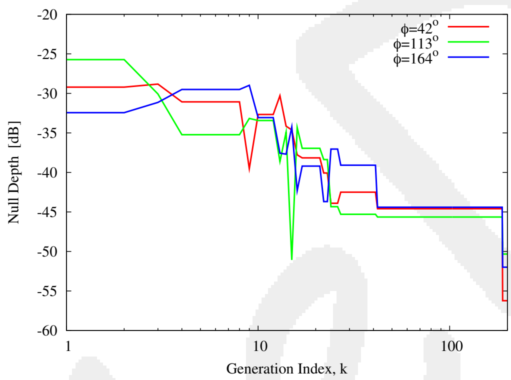

Fig.183 - Nulls Depth

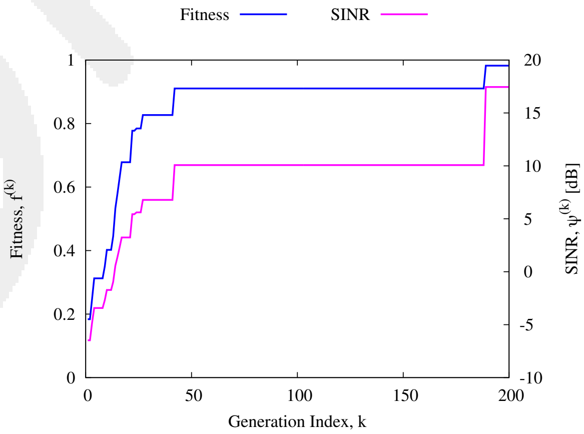

Fig.184 - Fitness - SINR

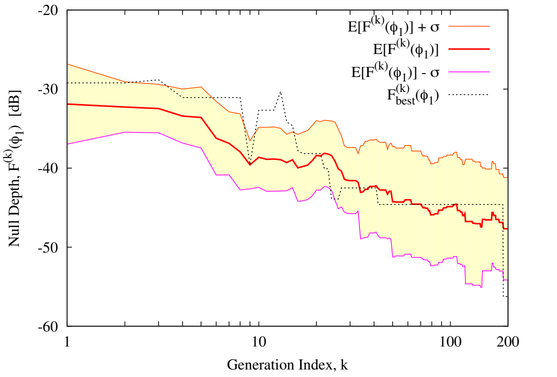

Fig.185 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

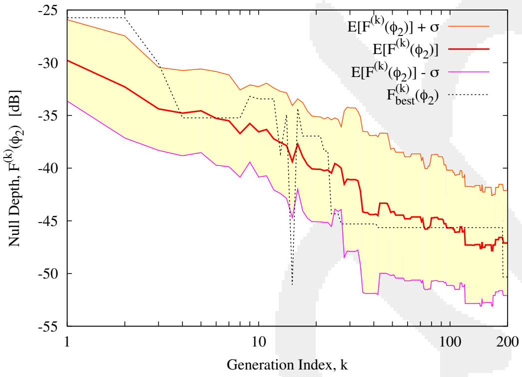

Fig.186 - Null Depth $\theta_2^i = 90°$, $\phi_2^i = 113°$ Statistics

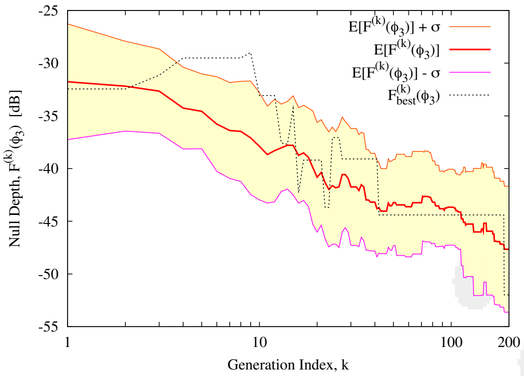

Fig.187 - Null Depth $\theta_3^i = 90°$, $\phi_3^i = 164°$ Statistics

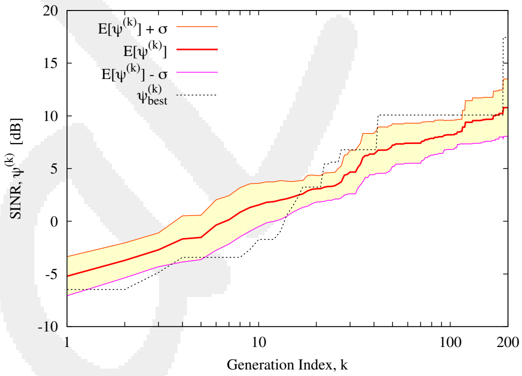

Fig.188 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$AF(\theta_2^i, \phi_2^i)$	$AF(\theta_3^i, \phi_3^i)$	*Nr. Active Elements*	$SINR\,[dB]$
GA	-56.23	-50.33	-51.99	82	17.45

Tab.30 - GA Simulation Results Analysis

TEST CASE 23 - 128 Elements - Fixed Scenario, Triple Interference - $\eta \in [0.50 - 0.70]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a triple interference.

Test Case Description

- Number of Elements $N = 128$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 3$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$, $\theta_3^i = 90°$, $\phi_3^i = 164°$

Optimization Approach: GA

- Number of Variables: $X = 128$ (α_n, $n = 1, ..., N$)
- Population: 64
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.50$
- Maximum Thinning Coefficient: $\eta_{max} = 0.70$
- Number of Repetitions for Statistical Analysis: 20

GA - 128 Elements - Triple Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$, $\theta_3^i = 90°$, $\phi_3^i = 164°$

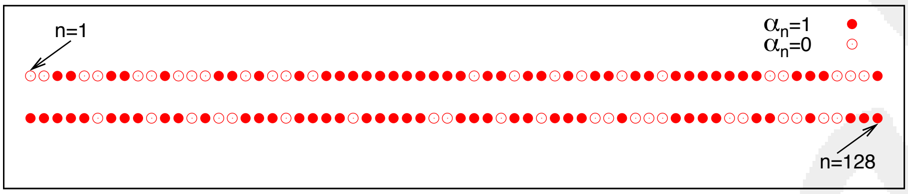

Fig.189 - Thinning Configuration

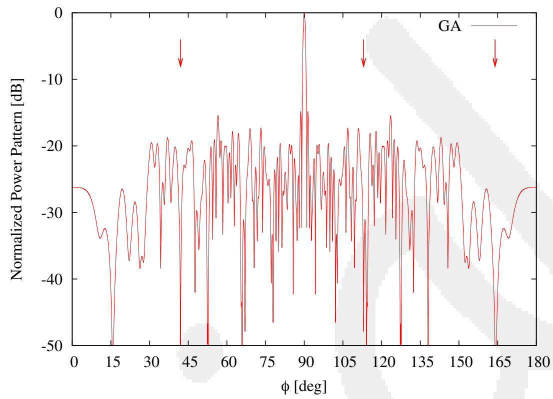

Fig.190 - Pattern

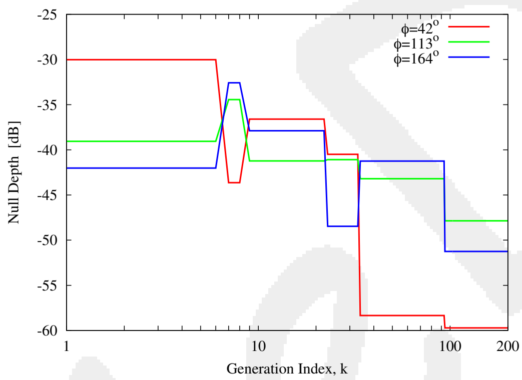

Fig.191 - Nulls Depth

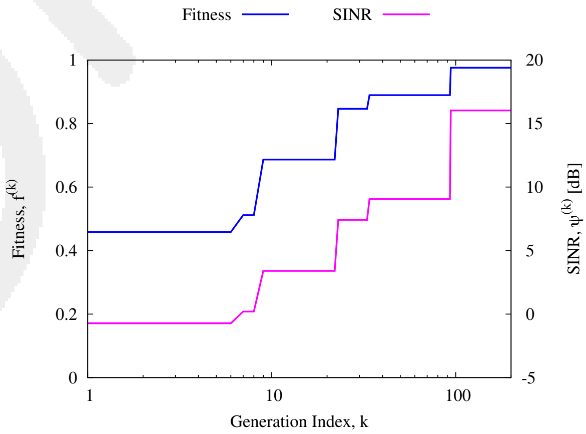

Fig.192 - Fitness - SINR

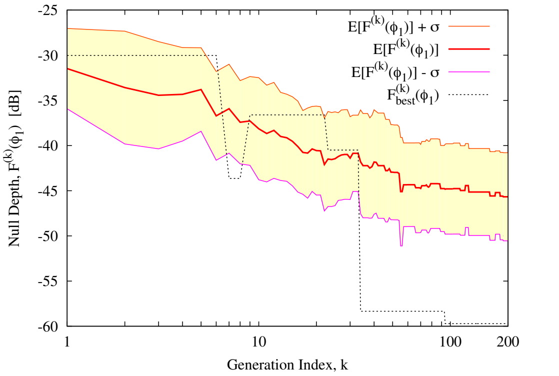

Fig.193 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

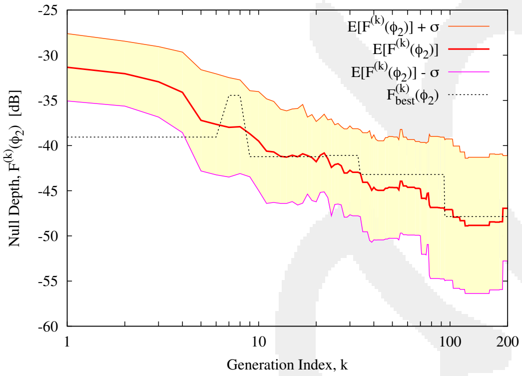

Fig.194 - Null Depth $\theta_2^i = 90°$, $\phi_2^i = 113°$ Statistics

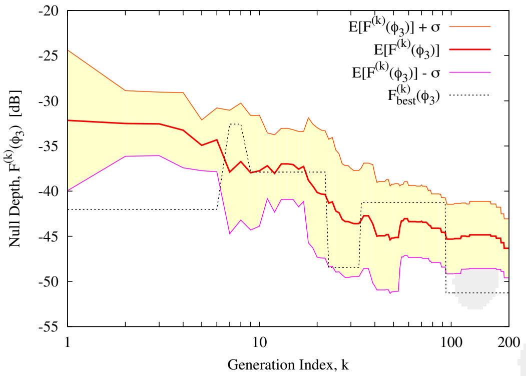

Fig.195 - Null Depth $\theta_3^i = 90°$, $\phi_3^i = 164°$ Statistics

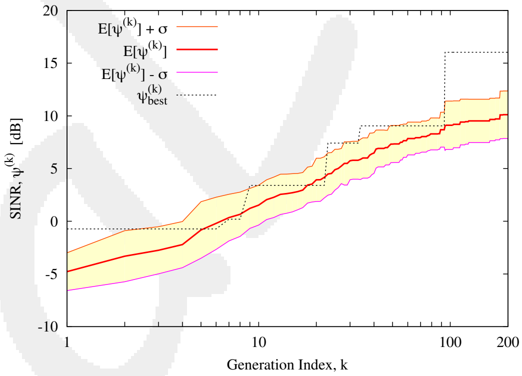

Fig.196 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$AF(\theta_2^i, \phi_2^i)$	$AF(\theta_3^i, \phi_3^i)$	$Nr. Active\ Elements$	$SINR\,[dB]$
GA	-59.71	-47.86	-51.25	82	16.03

Tab.31 - GA Simulation Results Analysis

TEST CASE 10 - 128 Elements - Fixed Scenario, Triple Interference - $\eta \in [0.60 - 0.60]$

Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned array configuration, considering a static scenario with a triple interference.

Test Case Description

- Number of Elements $N = 128$
- Elements Spacing: $d = 0.5\lambda$
- Max Gain Pattern Direction : $\theta^d = 90°$, $\phi^d = 90°$
- Desired Signal Power: $0\,dB$
- Interference Power: $30\,dB$
- Noise Power: $-30\,dB$
- Number of Interferences: $N^I = 3$
- Interference Direction Of Arrival: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$, $\theta_3^i = 90°$, $\phi_3^i = 164°$

Optimization Approach: GA

- Number of Variables: $X = 128$ (α_n, $n = 1, ..., N$)
- Population: 64
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: $\eta_{min} = 0.60$
- Maximum Thinning Coefficient: $\eta_{max} = 0.60$
- Number of Repetitions for Statistical Analysis: 20

GA - 128 Elements - Triple Interference: $\theta_1^i = 90°$, $\phi_1^i = 42°$, $\theta_2^i = 90°$, $\phi_2^i = 113°$, $\theta_3^i = 90°$, $\phi_3^i = 164°$

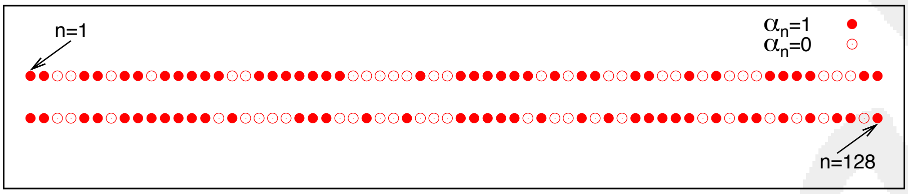

Fig.197 - Thinning Configuration

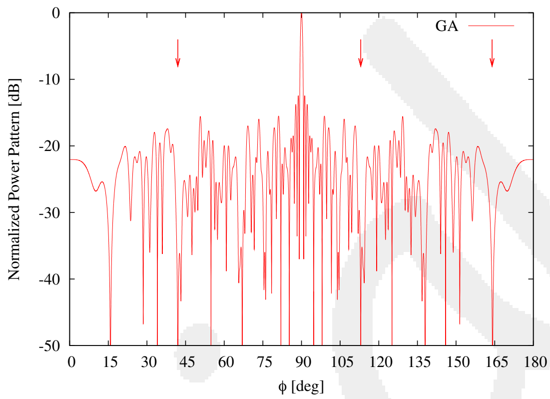

Fig.198 - Pattern

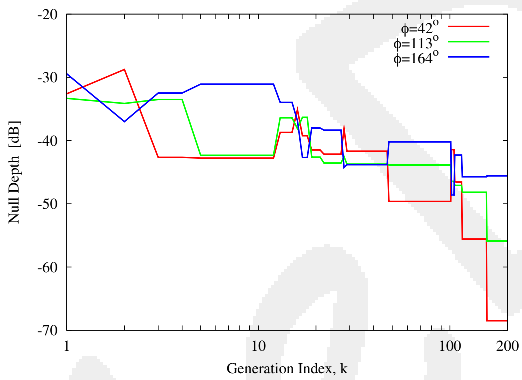

Fig.199 - Nulls Depth

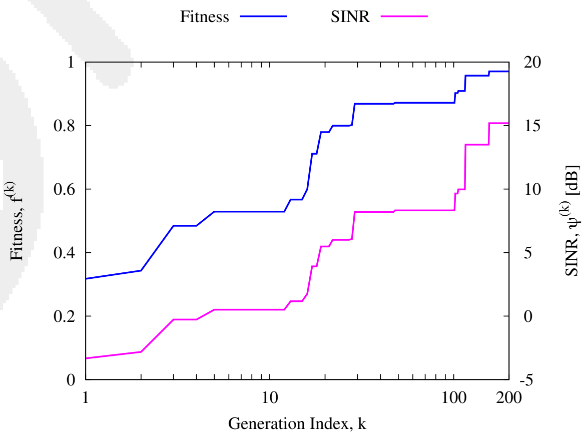

Fig.200 - Fitness - SINR

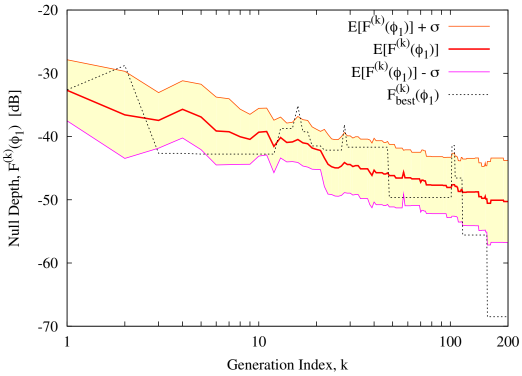

Fig.201 - Null Depth $\theta_1^i = 90°$, $\phi_1^i = 42°$ Statistics

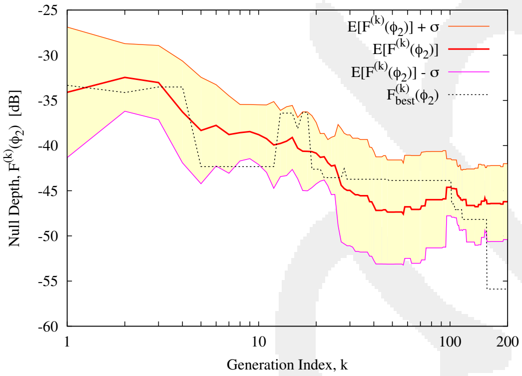

Fig.202 - Null Depth $\theta_2^i = 90°$, $\phi_2^i = 113°$ Statistics

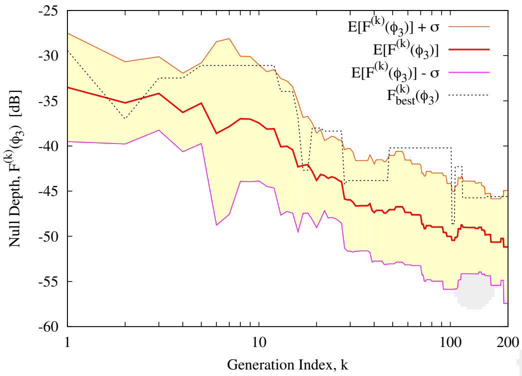

Fig.203 - Null Depth $\theta_3^i = 90°$, $\phi_3^i = 164°$ Statistics

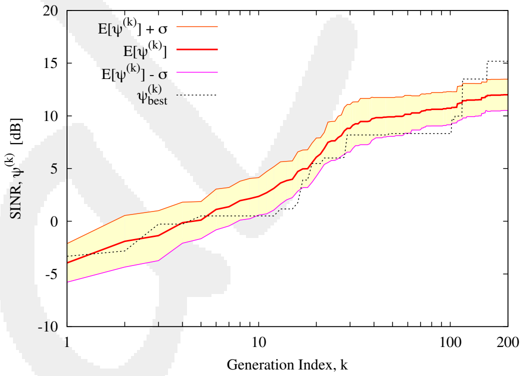

Fig.204 - SINR Statistics

	$AF(\theta_1^i, \phi_1^i)$	$AF(\theta_2^i, \phi_2^i)$	$AF(\theta_3^i, \phi_3^i)$	$Nr. Active Elements$	$SINR [dB]$
GA	-68.50	-55.89	-45.59	76	15.18

Tab.32 - GA Simulation Results Analysis

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