# Multi-interference suppression through a GA-based method for ring arrays

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**Abstract**

In this report, the nulling of multiple interferences or jammers impinging on a circular ring antenna array is addressed by means of an efficient adaptive control strategy based on a Genetic Algorithm.
Each element of the array is uniformly weighted and the nulling feature is yielded by controlling a set of radio-frequency switches that connect or disconnect the elements from the beam forming network. Representative result concerned with different interfering scenarios with multiple undesired signals are reported to assess the effectiveness of the approach.

## TEST CASE - $N = 37$ -$Configuration = 3rings$ -$\eta \in [0.0, 1.0]$ - $N_I = 2$

### Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned ring array configuration, considering a time-varying scenario with 2 interferences.

### Test Case Description

- Number of Elements $N = 37$
- 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: $\theta_1^i = 52°$, $\phi_1^i = 156°$
- Interference Direction Of Arrival: $\theta_2^i = 155°$, $\phi_2^i = 18°$

### Optimization Approach: GA

- Number of Variables: $X = 37$ ($\alpha_n$, $n = 1, ..., N$)
- Population: 18
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: 0.0
- Maximum Thinning Coefficient: 1.0

**GA - Multiple Interferences:** $\theta_1^i = 52°$, $\phi_1^i = 156°$; $\theta_2^i = 155°$, $\phi_2^i = 18°$

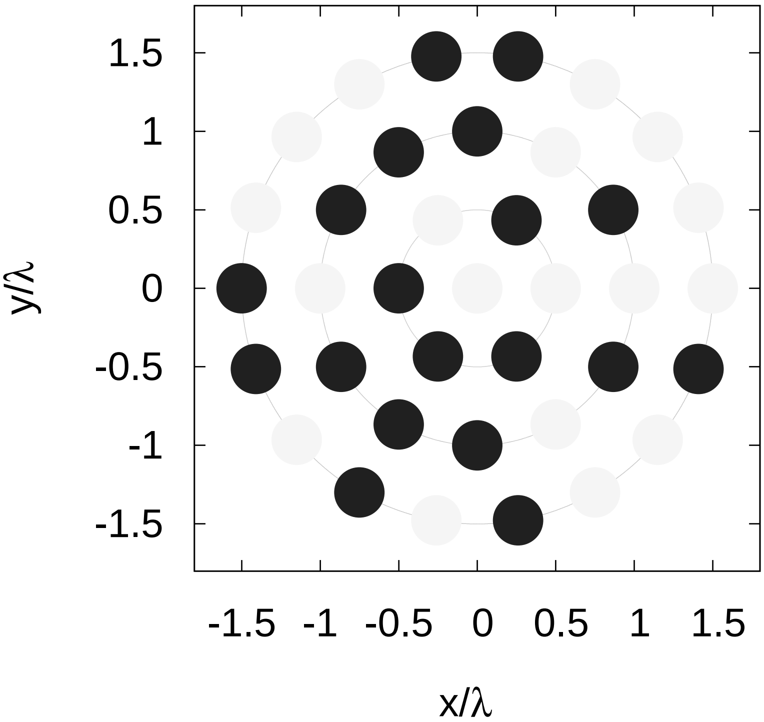


**Fig.1 - Thinning Configuration**

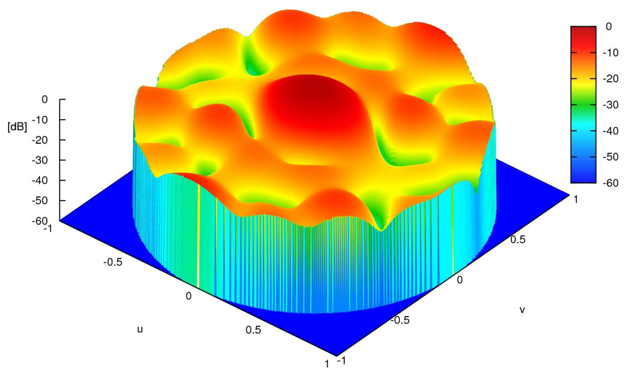


**Fig.2 - Pattern**

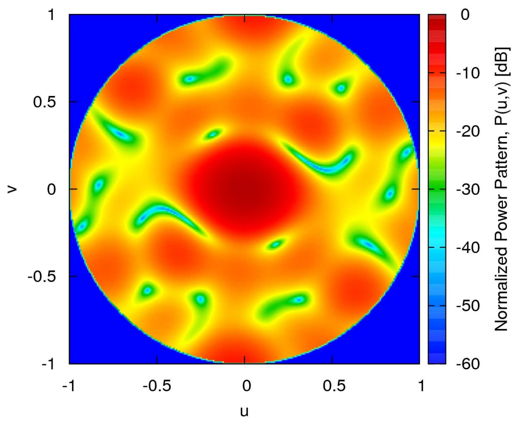


**Fig.3 - Pattern projection**

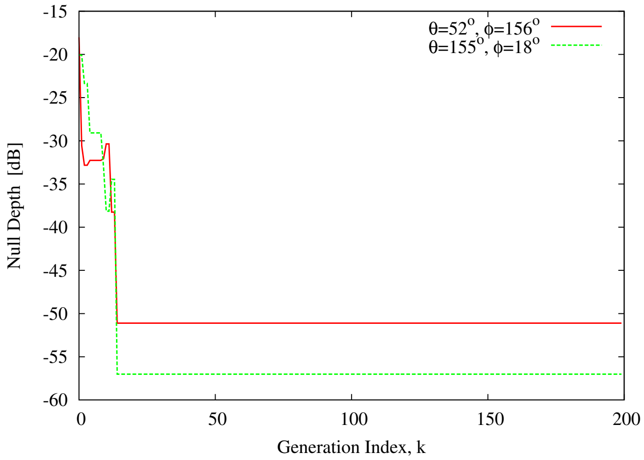


**Fig.4 - Nulls Depth 1**

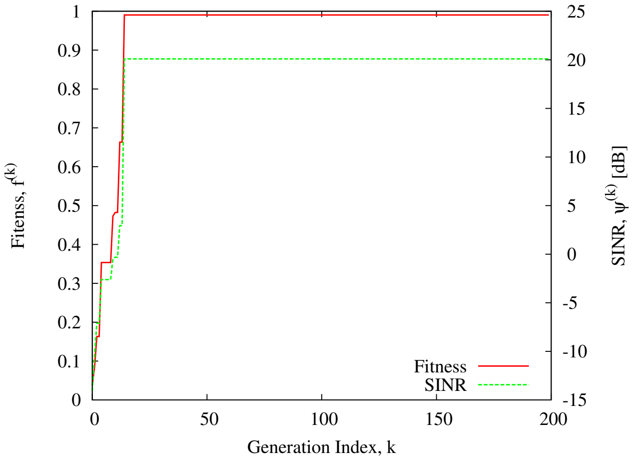


**Fig.5 - Fitness SINR**

SINR[dB]: 20.10

Null Depths[dB]: $[-51.11, -57]$

Number of Active Elements: 19

## TEST CASE - $N = 37$ -$Configuration = 3rings$ -$\eta \in [0.0, 1.0]$ - $N_I = 3$

### Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned ring array configuration, considering a time-varying scenario with 3 interferences.

### Test Case Description

- Number of Elements $N = 37$
- 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: $\theta_1^i = 36°$, $\phi_1^i = 64°$
- Interference Direction Of Arrival: $\theta_2^i = 95°$, $\phi_2^i = 123°$
- Interference Direction Of Arrival: $\theta_3^i = 20°$, $\phi_3^i = 23°$

### Optimization Approach: GA

- Number of Variables: $X = 37$ ($\alpha_n$, $n = 1, ..., N$)
- Population: 18
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: 0.0
- Maximum Thinning Coefficient: 1.0

**GA - Multiple Interferences:** $\theta_1^i = 36°$, $\phi_1^i = 64°$; $\theta_2^i = 95°$, $\phi_2^i = 123°$; $\theta_3^i = 20°$, $\phi_3^i = 23°$

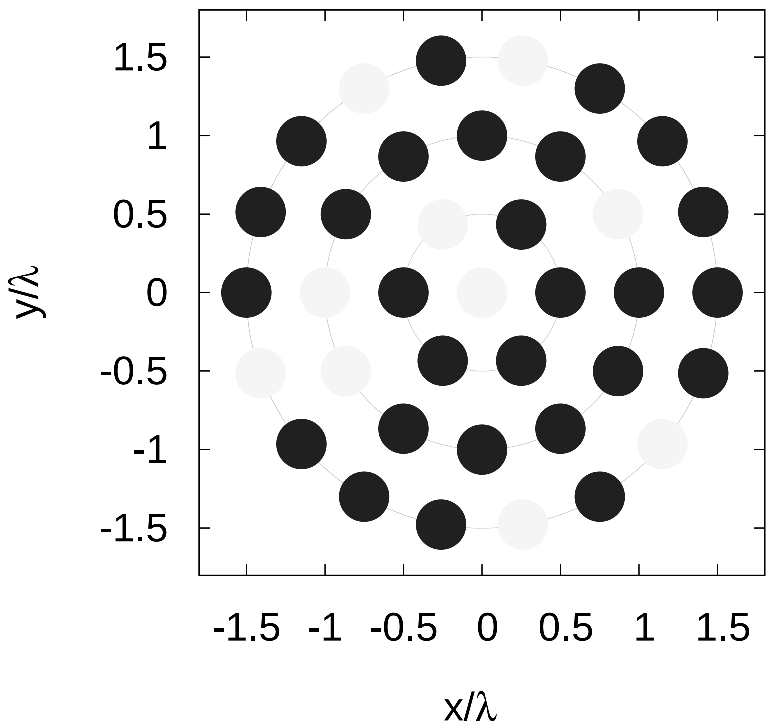


**Fig.1 - Thinning Configuration**

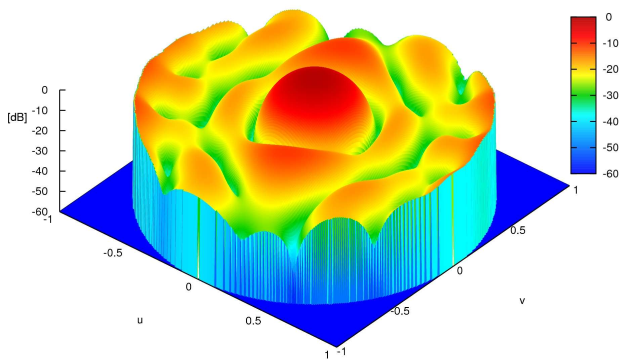


**Fig.2 - Pattern**

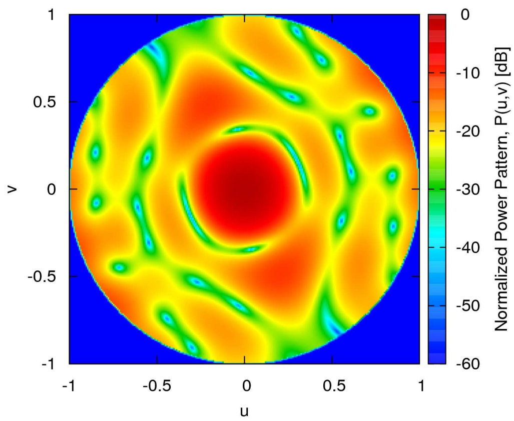


**Fig.3 - Pattern projection**

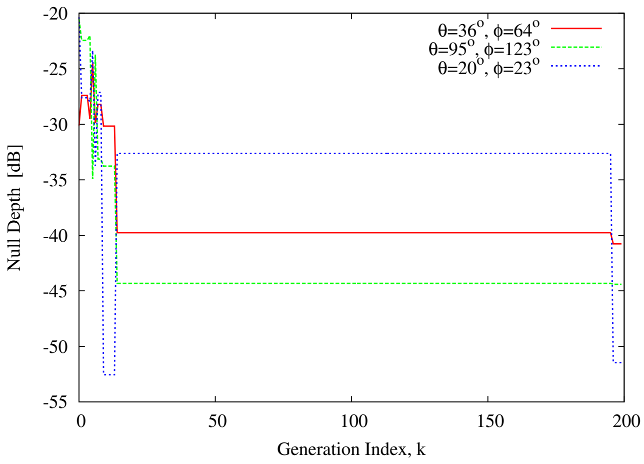


**Fig.4 - Nulls Depth 1**

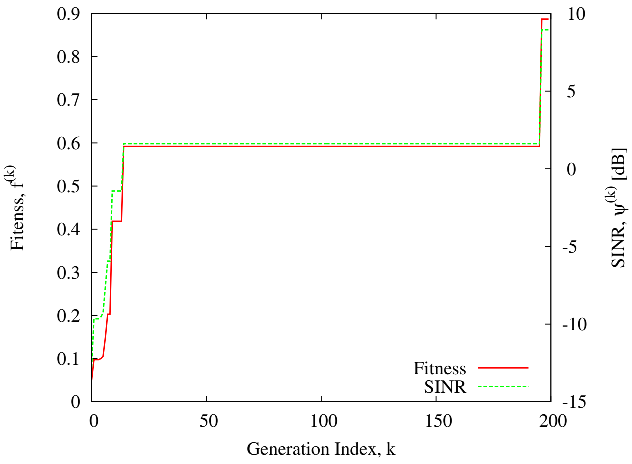


**Fig.5 - Fitness SINR**

SINR[dB]: 8.95

Null Depths[dB]: $[-40.76, -44.4, -51.45]$

Number of Active Elements: 27

## TEST CASE - $N = 37$ -$Configuration = 3rings$ -$\eta \in [0.0, 1.0]$ - $N_I = 4$

### Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned ring array configuration, considering a time-varying scenario with 4 interferences.

### Test Case Description

- Number of Elements $N = 37$
- 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: $N_I = 4$
- Interference Direction Of Arrival: $\theta_1^i = 84°$, $\phi_1^i = 2°$
- Interference Direction Of Arrival: $\theta_2^i = 97°$, $\phi_2^i = 165°$
- Interference Direction Of Arrival: $\theta_3^i = 90°$, $\phi_3^i = 136°$
- Interference Direction Of Arrival: $\theta_4^i = 148°$, $\phi_4^i = 20°$

### Optimization Approach: GA

- Number of Variables: $X = 37$ ($\alpha_n$, $n = 1, ..., N$)
- Population: 18
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: 0.0
- Maximum Thinning Coefficient: 1.0

**GA - Multiple Interferences:** $\theta_1^i = 84°$, $\phi_1^i = 2°$; $\theta_2^i = 97°$, $\phi_2^i = 165°$; $\theta_3^i = 90°$, $\phi_3^i = 136°$; $\theta_4^i = 148°$, $\phi_4^i = 20°$

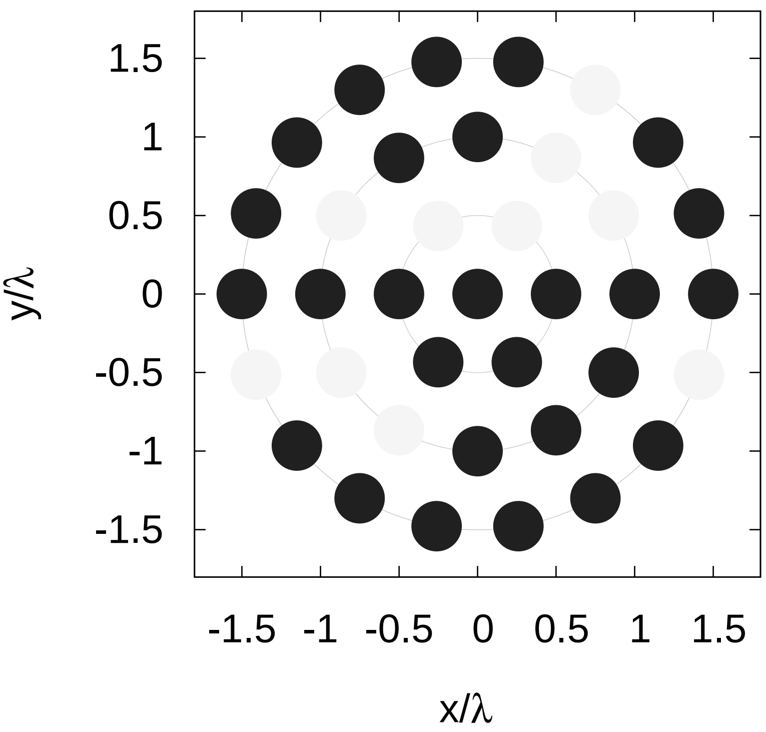


**Fig.1 - Thinning Configuration**

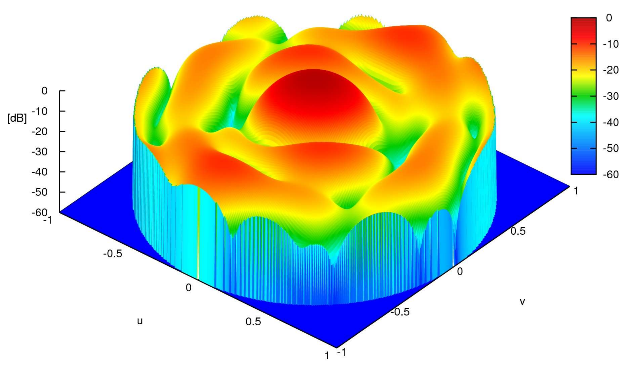


**Fig.2 - Pattern**

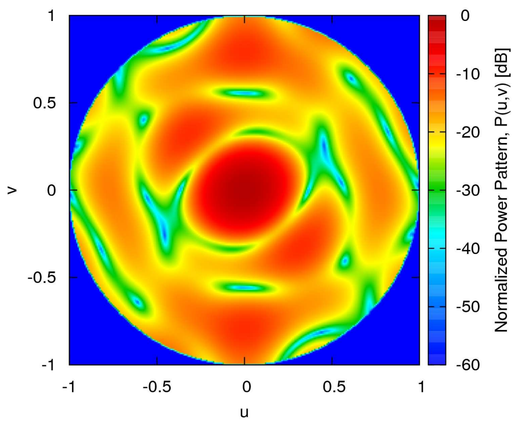


**Fig.3 - Pattern projection**

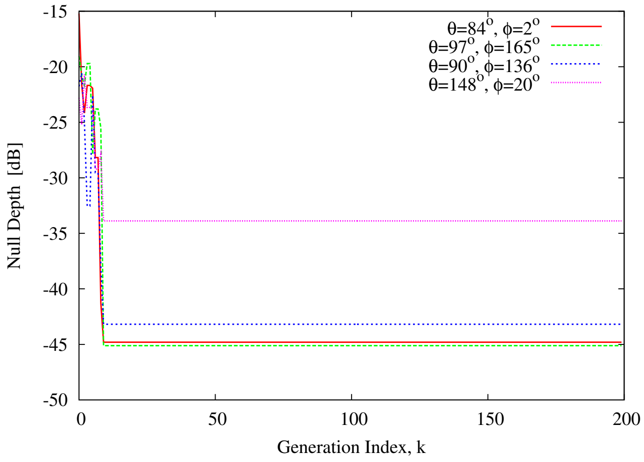


**Fig.4 - Nulls Depth 1**

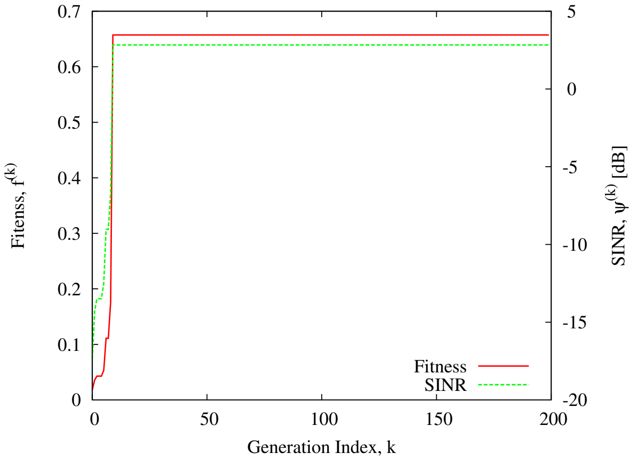


**Fig.5 - Fitness SINR**

SINR[dB]: 2.82

Null Depths[dB]: [−44.8, −45.11, −43.18, −33.87]

Number of Active Elements: 27

## TEST CASE - $N = 37$ -$Configuration = 3rings$ -$\eta \in [0.0, 1.0]$ - $N_I = 5$

### Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned ring array configuration, considering a time-varying scenario with 5 interferences.

### Test Case Description

- Number of Elements $N = 37$
- 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: $N_I = 5$
- Interference Direction Of Arrival: $\theta_1^i = 97°$, $\phi_1^i = 132°$
- Interference Direction Of Arrival: $\theta_2^i = 161°$, $\phi_2^i = 41°$
- Interference Direction Of Arrival: $\theta_3^i = 27°$, $\phi_3^i = 166°$
- Interference Direction Of Arrival: $\theta_4^i = 114°$, $\phi_4^i = 49°$
- Interference Direction Of Arrival: $\theta_5^i = 104°$, $\phi_5^i = 100°$

### Optimization Approach: GA

- Number of Variables: $X = 37$ ($\alpha_n$, $n = 1, ..., N$)
- Population: 18
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: 0.0
- Maximum Thinning Coefficient: 1.0

**GA - Multiple Interferences:** $\theta_1^i = 97°$, $\phi_1^i = 132°$; $\theta_2^i = 161°$, $\phi_2^i = 41°$; $\theta_3^i = 27°$, $\phi_3^i = 166°$; $\theta_4^i = 114°$, $\phi_4^i = 49°$; $\theta_5^i = 104°$, $\phi_5^i = 100°$

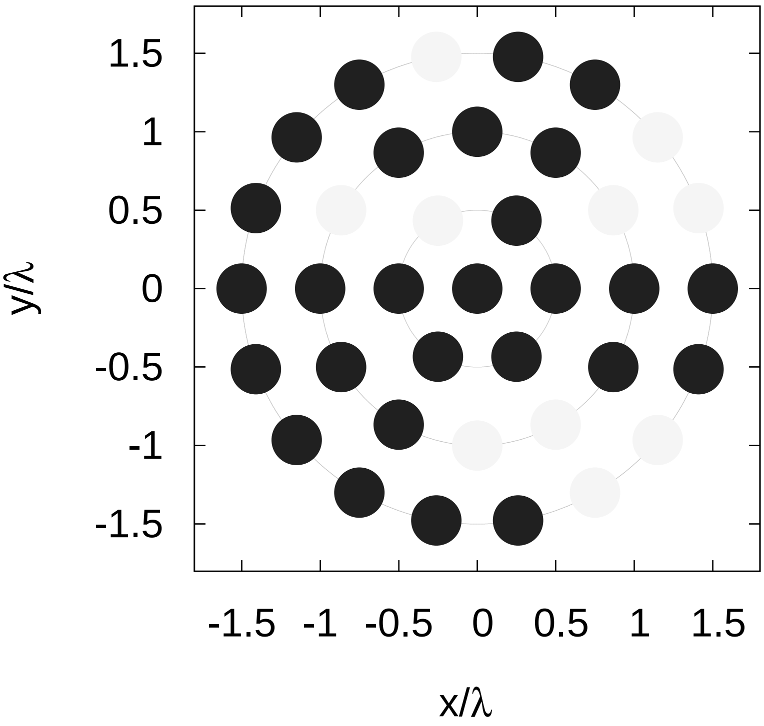


**Fig.1 - Thinning Configuration**

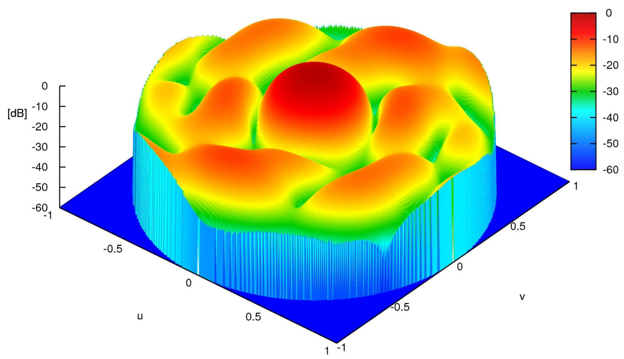


**Fig.2 - Pattern**

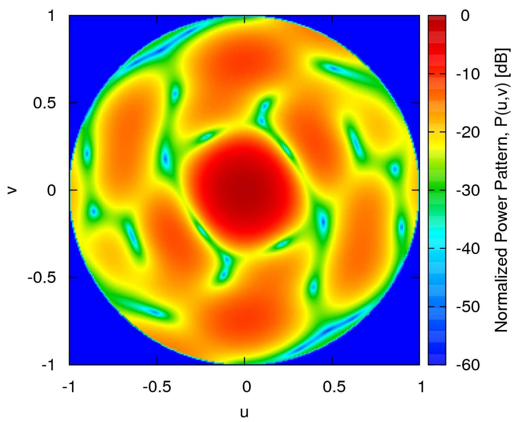


**Fig.3 - Pattern projection**

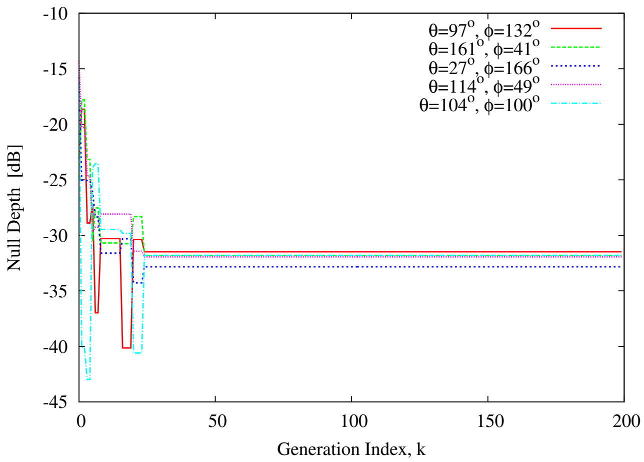


**Fig.4 - Nulls Depth 1**

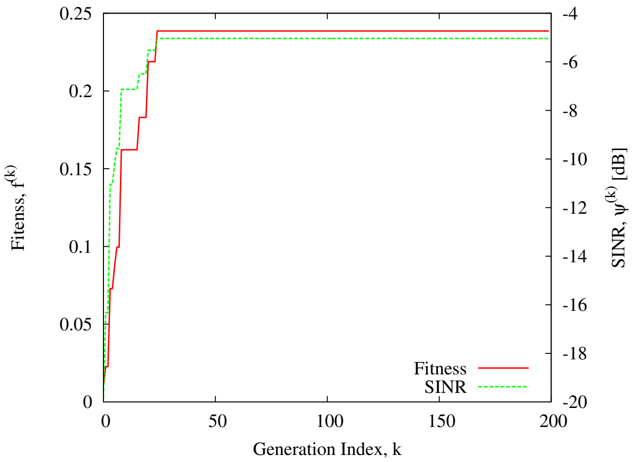


**Fig.5 - Fitness SINR**

SINR[dB]: $-5.03$

Null Depths[dB]: $[-31.47, -31.81, -32.83, -31.94, -31.79]$

Number of Active Elements:27

**TEST CASE -** $N = 91$ **-**$Configuration = 5rings$ **-**$\eta \in [0.0, 1.0]$ **-** $N_I = 2$

**Goal**

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned ring array configuration, considering a time-varying scenario with 2 interferences.

**Test Case Description**

- Number of Elements $N = 91$
- 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: $\theta_1^i = 113°$, $\phi_1^i = 157°$
- Interference Direction Of Arrival: $\theta_2^i = 55°$, $\phi_2^i = 22°$

**Optimization Approach: GA**

- Number of Variables: $X = 91$ ($\alpha_n$, $n = 1, ..., N$)
- Population: 46
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: 0.0
- Maximum Thinning Coefficient: 1.0

**GA - Multiple Interferences:** $\theta_1^i = 113°$, $\phi_1^i = 157°$; $\theta_2^i = 55°$, $\phi_2^i = 22°$

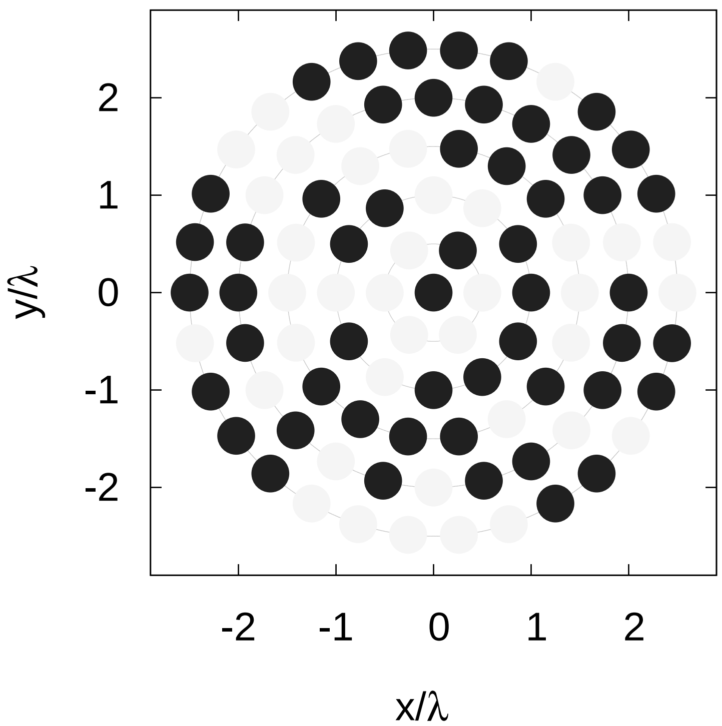


**Fig.1 - Thinning Configuration**

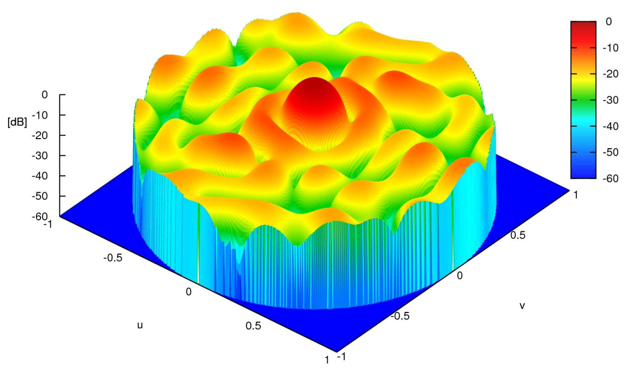


**Fig.2 - Pattern**

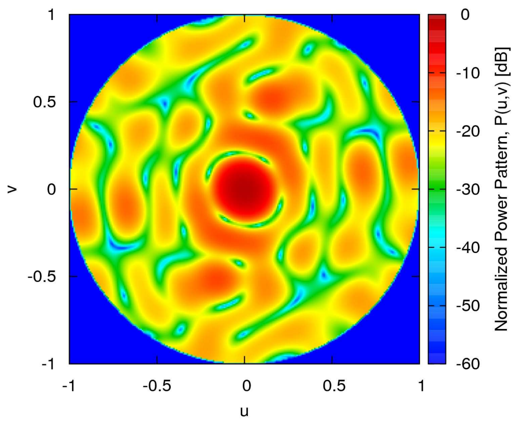


**Fig.3 - Pattern projection**

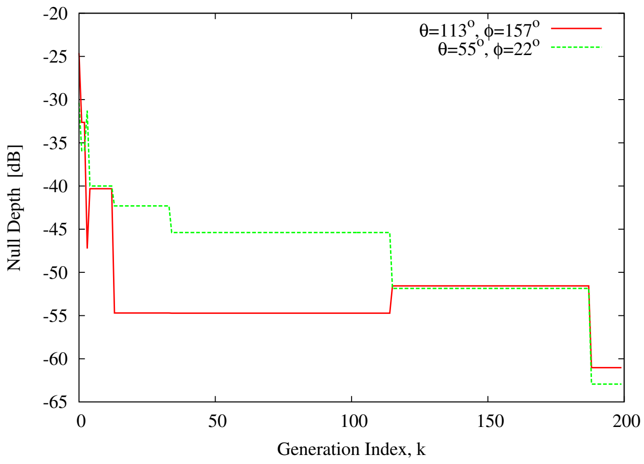


**Fig.4 - Nulls Depth 1**

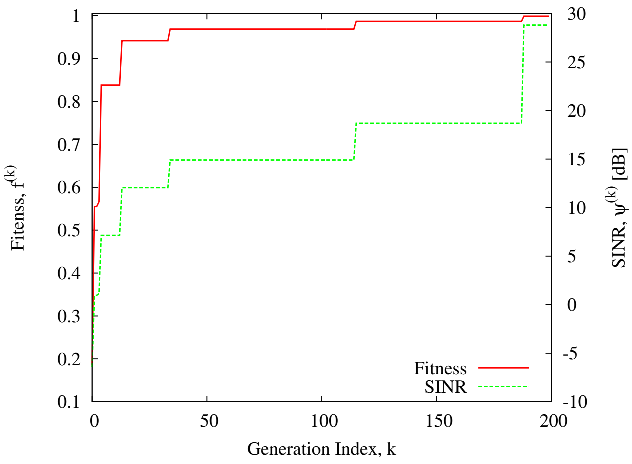


**Fig.5 - Fitness SINR**

SINR[dB]: 28.8

Null Depths[dB]: $[-61.03, -62.93]$

Number of Active Elements: 53

## TEST CASE - $N = 91$ -$Configuration = 5rings$ -$\eta \in [0.0, 1.0]$ - $N_I = 3$

### Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned ring array configuration, considering a time-varying scenario with 3 interferences.

### Test Case Description

- Number of Elements $N = 91$
- 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: $\theta_1^i = 34°$, $\phi_1^i = 191°$
- Interference Direction Of Arrival: $\theta_2^i = 99°$, $\phi_2^i = 32°$
- Interference Direction Of Arrival: $\theta_3^i = 164°$, $\phi_3^i = 96°$

### Optimization Approach: GA

- Number of Variables: $X = 91$ ($\alpha_n$, $n = 1, ..., N$)
- Population: 46
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: 0.0
- Maximum Thinning Coefficient: 1.0

**GA - Multiple Interferences:** $\theta_1^i = 34°$, $\phi_1^i = 191°$; $\theta_2^i = 99°$, $\phi_2^i = 32°$; $\theta_3^i = 164°$, $\phi_3^i = 96°$

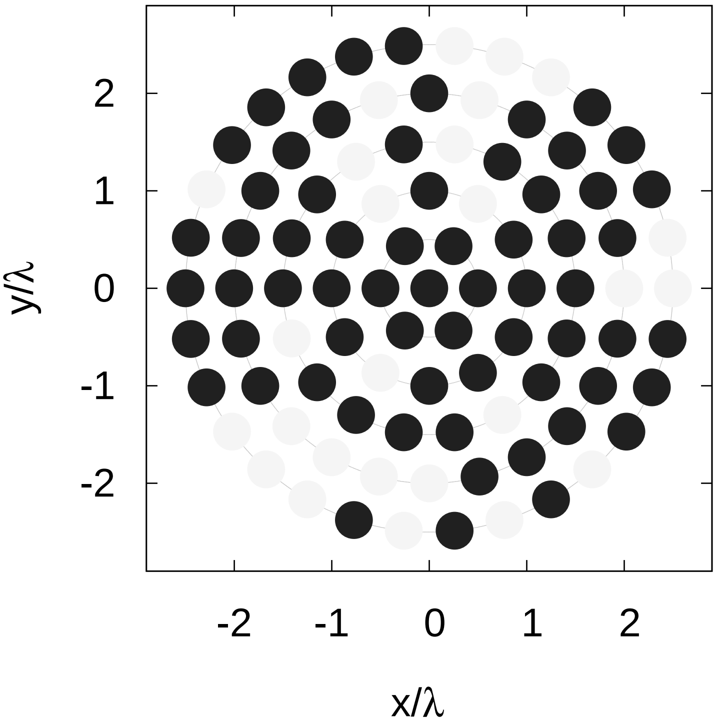


**Fig.1 - Thinning Configuration**

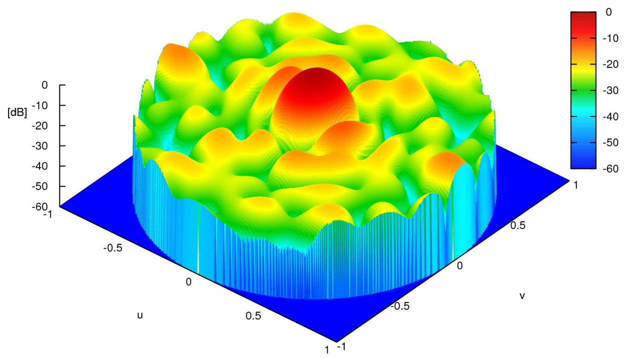


**Fig.2 - Pattern**

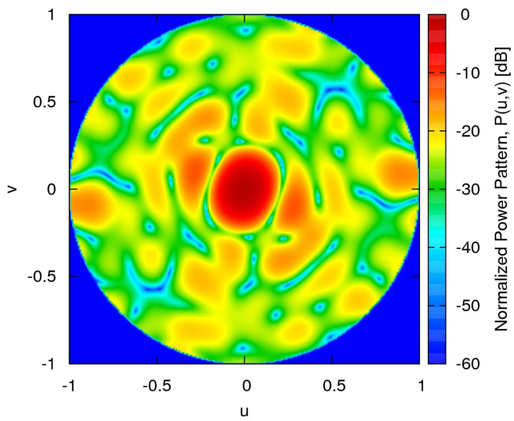


**Fig.3 - Pattern projection**

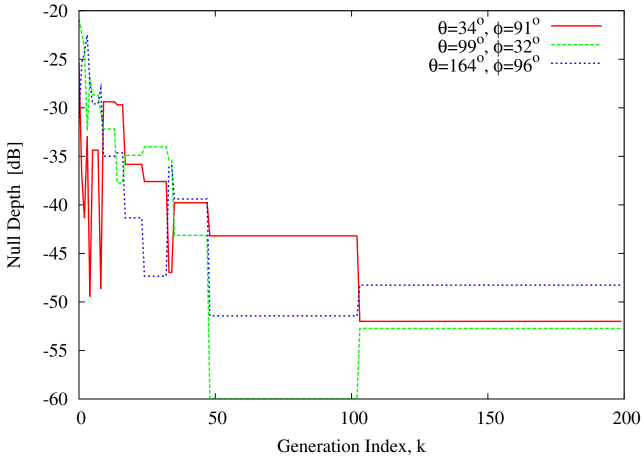


**Fig.4 - Nulls Depth 1**

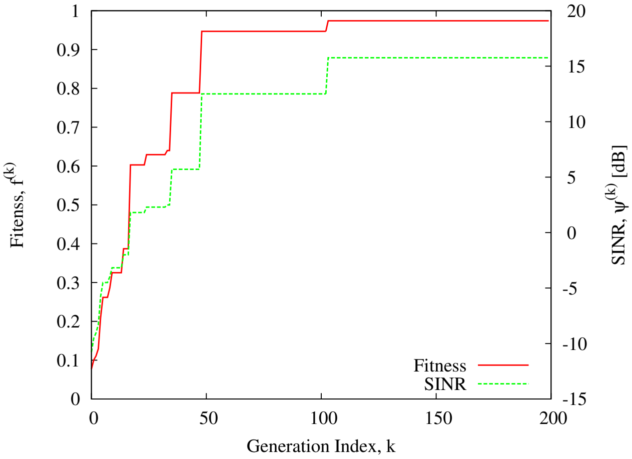


**Fig.5 - Fitness SINR**

SINR[dB]: 15.75

Null Depths[dB]: $[-52, -52.73, -48.27]$

Number of Active Elements: 65

## TEST CASE - $N = 91$ -$Configuration = 5rings$ -$\eta \in [0.0, 1.0]$ - $N_I = 4$

### Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned ring array configuration, considering a time-varying scenario with 4 interferences.

### Test Case Description

- Number of Elements $N = 91$
- 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: $N_I = 4$
- Interference Direction Of Arrival: $\theta_1^i = 89°$, $\phi_1^i = 73°$
- Interference Direction Of Arrival: $\theta_2^i = 70°$, $\phi_2^i = 15°$
- Interference Direction Of Arrival: $\theta_3^i = 69°$, $\phi_3^i = 131°$
- Interference Direction Of Arrival: $\theta_4^i = 28°$, $\phi_4^i = 135°$

### Optimization Approach: GA

- Number of Variables: $X = 91$ ($\alpha_n$, $n = 1, ..., N$)
- Population: 46
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: 0.0
- Maximum Thinning Coefficient: 1.0

**GA - Multiple Interferences:** $\theta_1^i = 89°$, $\phi_1^i = 73°$; $\theta_2^i = 70°$, $\phi_2^i = 15°$; $\theta_3^i = 69°$, $\phi_3^i = 131°$; $\theta_4^i = 28°$, $\phi_4^i = 135°$

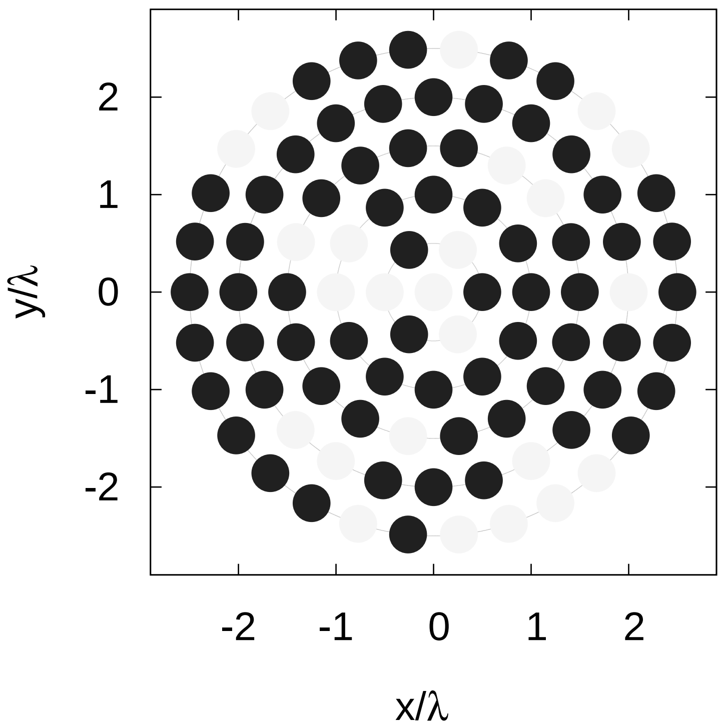


**Fig.1 - Thinning Configuration**

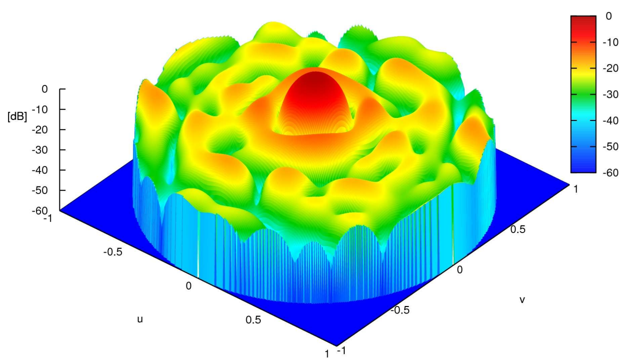


**Fig.2 - Pattern**

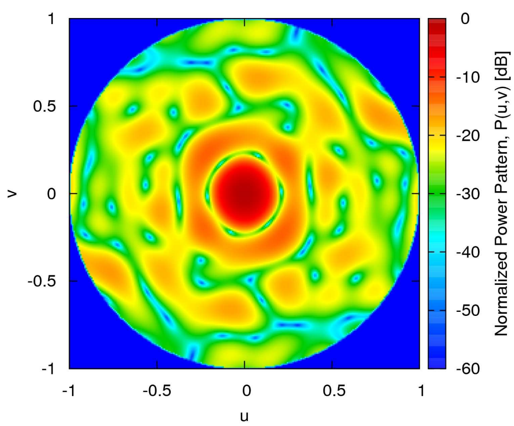


**Fig.3 - Pattern projection**

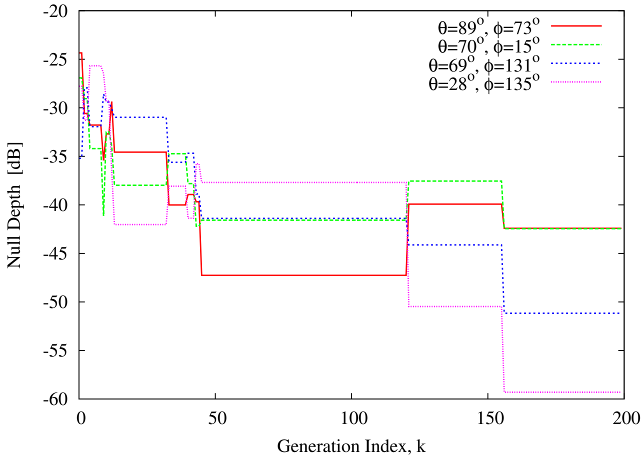


**Fig.4 - Nulls Depth 1**

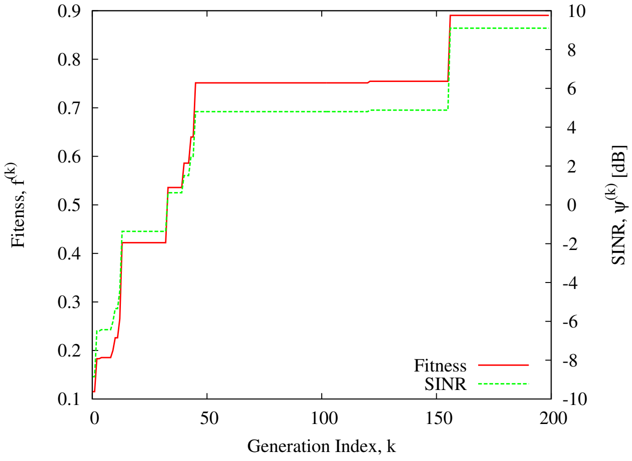


**Fig.5 - Fitness SINR**

SINR[dB]: 9.10

Null Depths[dB]: $[-42.41, -42.44, -51.16, -59.29]$

Number of Active Elements: 67

## TEST CASE - $N = 91$ -$Configuration = 5rings$ -$\eta \in [0.0, 1.0]$ - $N_I = 5$

### Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned ring array configuration, considering a time-varying scenario with 5 interferences.

### Test Case Description

- Number of Elements $N = 91$
- 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: $N_I = 5$
- Interference Direction Of Arrival: $\theta_1^i = 79°$, $\phi_1^i = 98°$
- Interference Direction Of Arrival: $\theta_2^i = 136°$, $\phi_2^i = 80°$
- Interference Direction Of Arrival: $\theta_3^i = 55°$, $\phi_3^i = 58°$
- Interference Direction Of Arrival: $\theta_4^i = 90°$, $\phi_4^i = 2°$
- Interference Direction Of Arrival: $\theta_5^i = 9°$, $\phi_5^i = 48°$

### Optimization Approach: GA

- Number of Variables: $X = 91$ ($\alpha_n$, $n = 1, ..., N$)
- Population: 46
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: 0.0
- Maximum Thinning Coefficient: 1.0

**GA - Multiple Interferences:** $\theta_1^i = 79°$, $\phi_1^i = 98°$; $\theta_2^i = 136°$, $\phi_2^i = 80°$; $\theta_3^i = 55°$, $\phi_3^i = 58°$; $\theta_4^i = 90°$, $\phi_4^i = 2°$; $\theta_5^i = 9°$, $\phi_5^i = 48°$

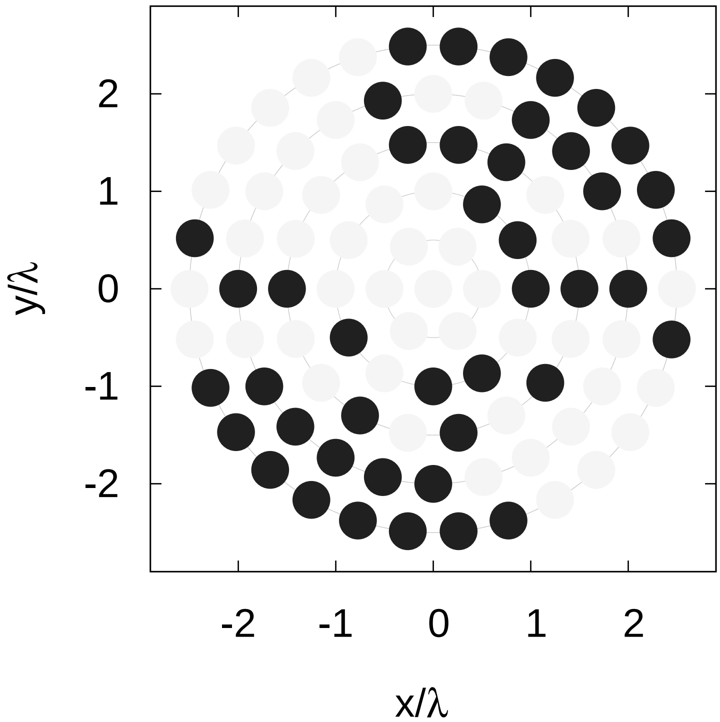


**Fig.1 - Thinning Configuration**

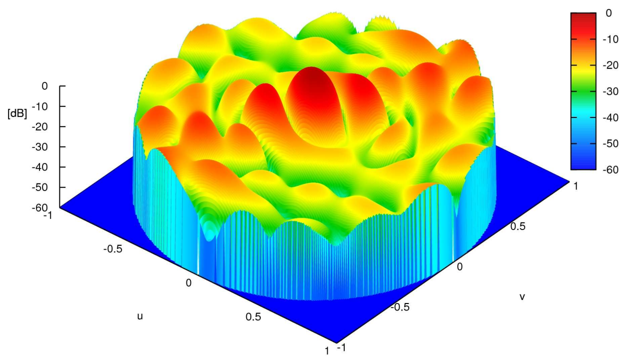


**Fig.2 - Pattern**

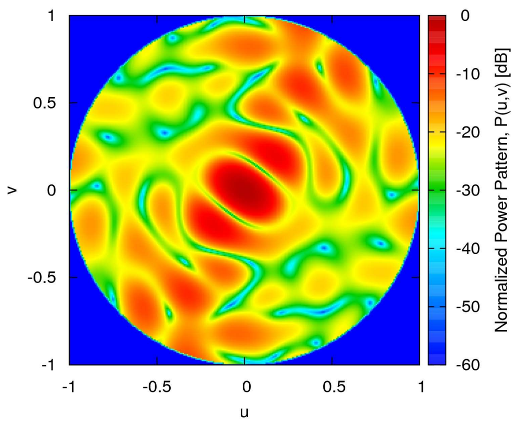


**Fig.3 - Pattern projection**

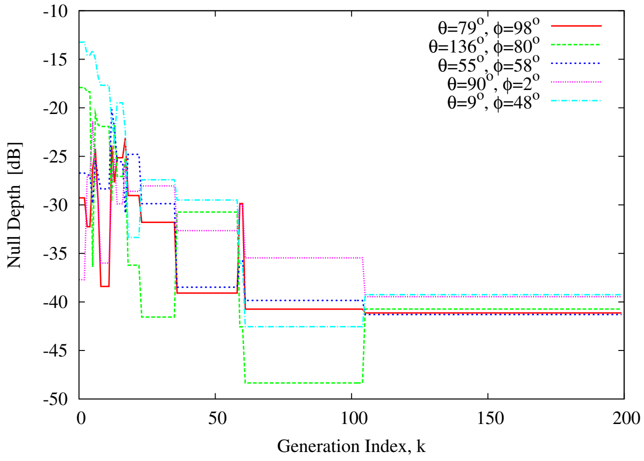


**Fig.4 - Nulls Depth 1**

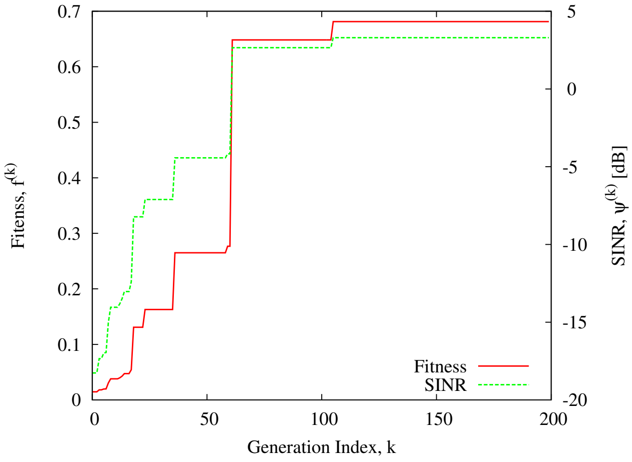


**Fig.5 - Fitness SINR**

SINR[dB]: 3.3

Null Depths[dB]: [−41.13, −40.73, −41.29, −39.46, −39.24]

Number of Active Elements:43

## TEST CASE - $N = 172$ -$Configuration = 7rings$ -$\eta \in [0.0, 1.0]$ - $N_I = 2$

### Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned ring array configuration, considering a time-varying scenario with 2 interferences.

### Test Case Description

- Number of Elements $N = 172$
- 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: $\theta_1^i = 144°$, $\phi_1^i = 165°$
- Interference Direction Of Arrival: $\theta_2^i = 35°$, $\phi_2^i = 166°$

### Optimization Approach: GA

- Number of Variables: $X = 172$ ($\alpha_n$, $n = 1, ..., N$)
- Population: 86
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: 0.0
- Maximum Thinning Coefficient: 1.0

**GA - Multiple Interferences:** $\theta_1^i = 144°$, $\phi_1^i = 165°$; $\theta_2^i = 35°$, $\phi_2^i = 166°$

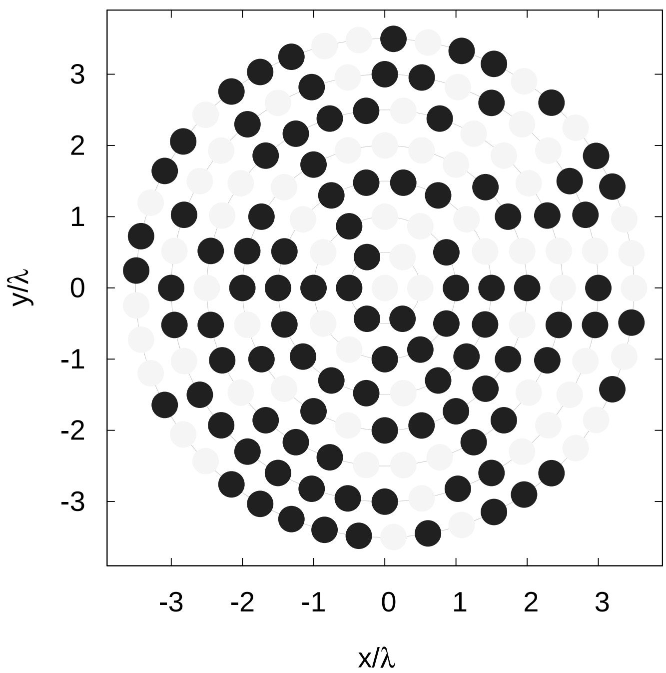


**Fig.1 - Thinning Configuration**

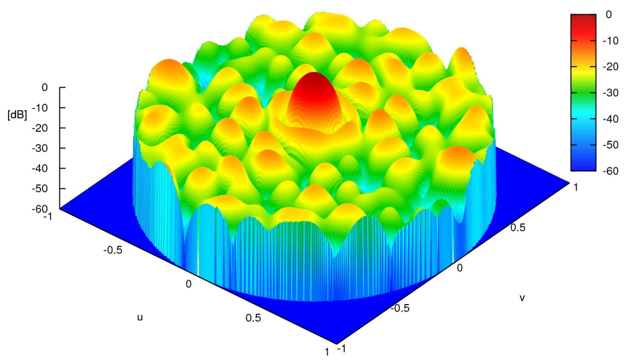


**Fig.2 - Pattern**

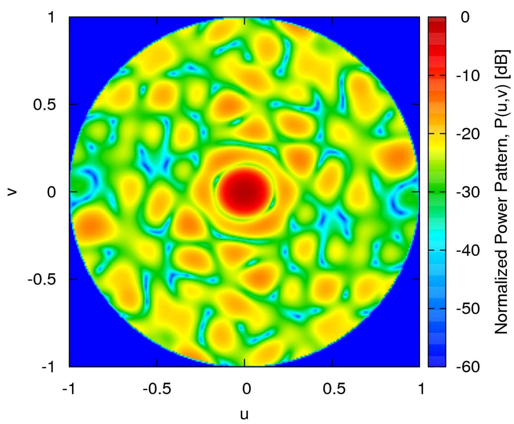


**Fig.3 - Pattern projection**

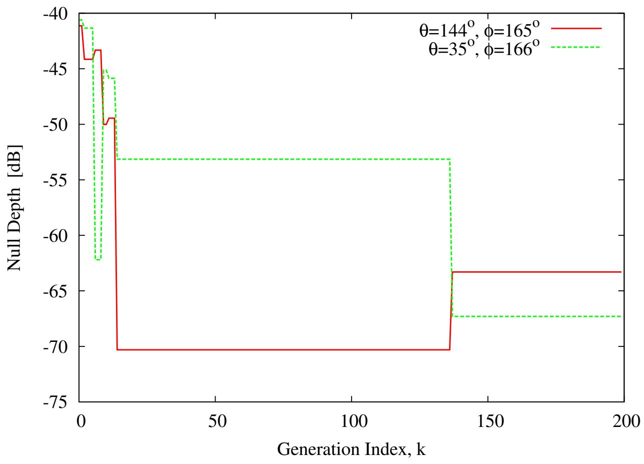


**Fig.4 - Nulls Depth 1**

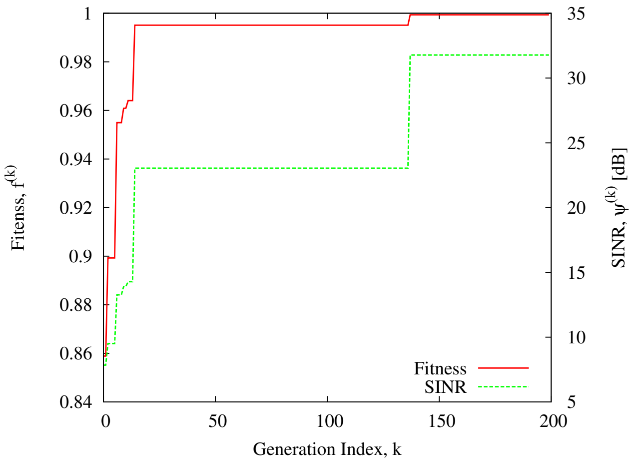


**Fig.5 - Fitness SINR**

SINR[dB]: 31.77

Null Depths[dB]: $[-63.29, -67.30]$

Number of Active Elements: 101

**TEST CASE -** $N = 172$ **-**$Configuration = 7rings$ **-**$\eta \in [0.0, 1.0]$ **-** $N_I = 3$

**Goal**

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned ring array configuration, considering a time-varying scenario with 3 interferences.

**Test Case Description**

- Number of Elements $N = 172$
- 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: $\theta_1^i = 51°$, $\phi_1^i = 96°$
- Interference Direction Of Arrival: $\theta_2^i = 19°$, $\phi_2^i = 63°$
- Interference Direction Of Arrival: $\theta_3^i = 32°$, $\phi_3^i = 91°$

**Optimization Approach: GA**

- Number of Variables: $X = 172$ ($\alpha_n$, $n = 1, ..., N$)
- Population: 86
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: 0.0
- Maximum Thinning Coefficient: 1.0

**GA - Multiple Interferences:** $\theta_1^i = 51°$, $\phi_1^i = 96°$; $\theta_2^i = 19°$, $\phi_2^i = 63°$; $\theta_3^i = 32°$, $\phi_3^i = 91°$

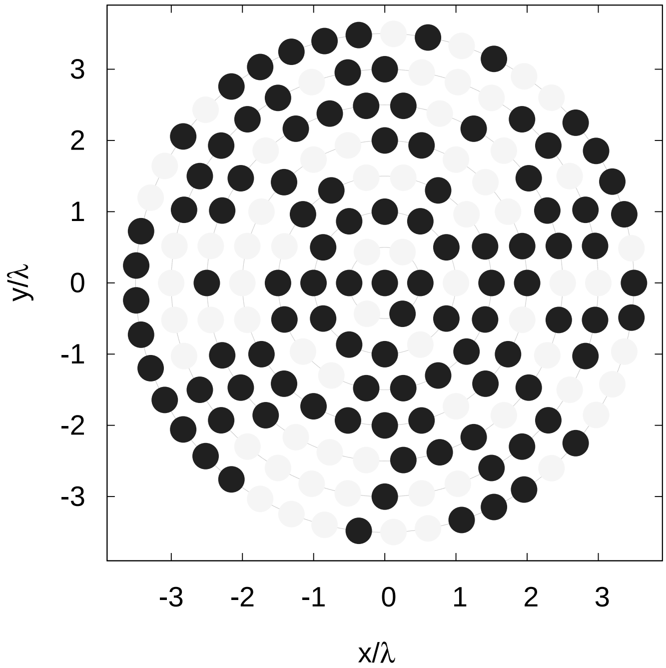


**Fig.1 - Thinning Configuration**

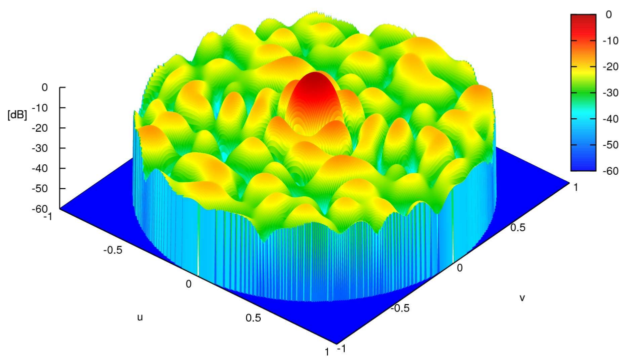


**Fig.2 - Pattern**

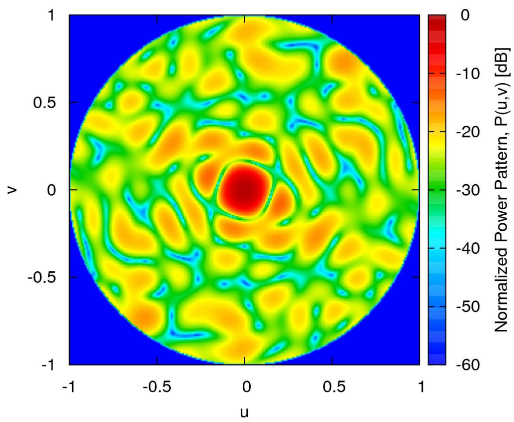


**Fig.3 - Pattern projection**

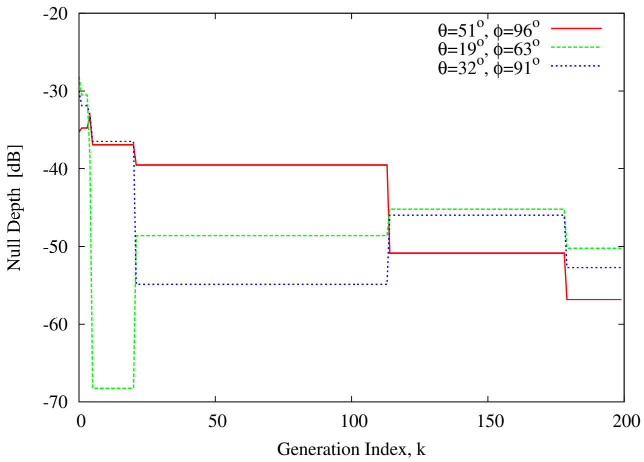


**Fig.4 - Nulls Depth 1**

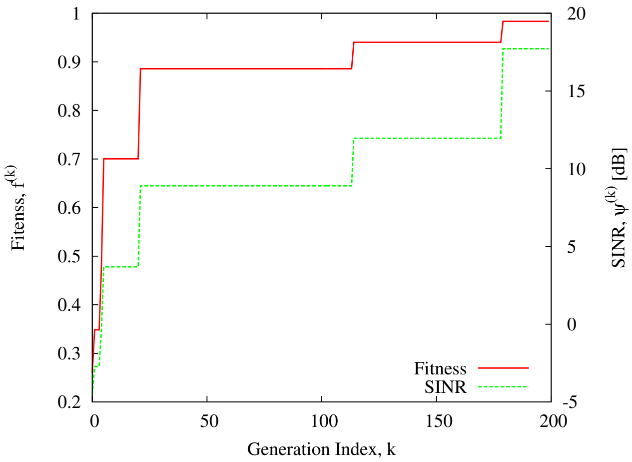


**Fig.5 - Fitness SINR**

SINR[dB]: 17.71

Null Depths[dB]: $[-56.82, -50.22, -52.72]$

Number of Active Elements: 105

**TEST CASE -** $N = 172$ **-**$Configuration = 7rings$ **-**$\eta \in [0.0, 1.0]$ **-** $N_I = 4$

**Goal**

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned ring array configuration, considering a time-varying scenario with 4 interferences.

**Test Case Description**

- Number of Elements $N = 172$
- 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: $N_I = 4$
- Interference Direction Of Arrival: $\theta_1^i = 16°$, $\phi_1^i = 160°$
- Interference Direction Of Arrival: $\theta_2^i = 103°$, $\phi_2^i = 132°$
- Interference Direction Of Arrival: $\theta_3^i = 165°$, $\phi_3^i = 34°$
- Interference Direction Of Arrival: $\theta_4^i = 107°$, $\phi_4^i = 133°$

**Optimization Approach: GA**

- Number of Variables: $X = 172$ ($\alpha_n$, $n = 1, ..., N$)
- Population: 86
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: 0.0
- Maximum Thinning Coefficient: 1.0

**GA - Multiple Interferences:** $\theta_1^i = 16°$, $\phi_1^i = 160°$; $\theta_2^i = 103°$, $\phi_2^i = 132°$; $\theta_3^i = 165°$, $\phi_3^i = 34°$; $\theta_4^i = 107°$, $\phi_4^i = 133°$

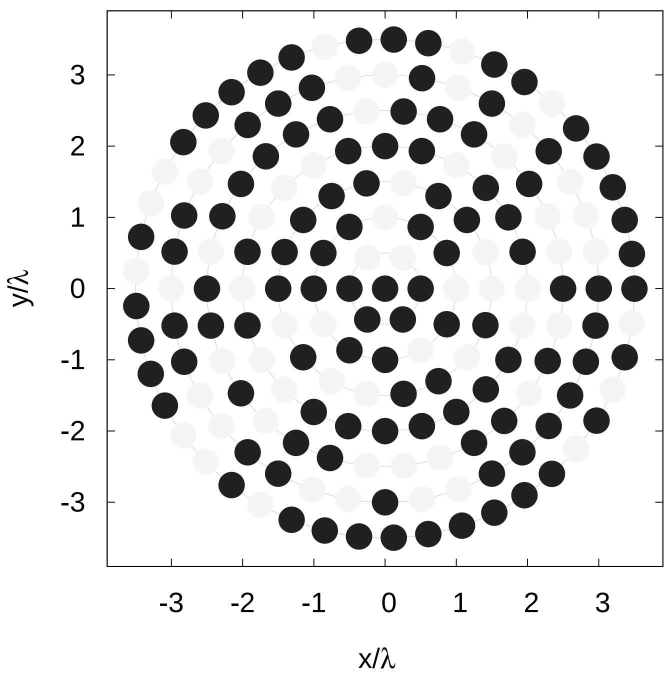


**Fig.1 - Thinning Configuration**

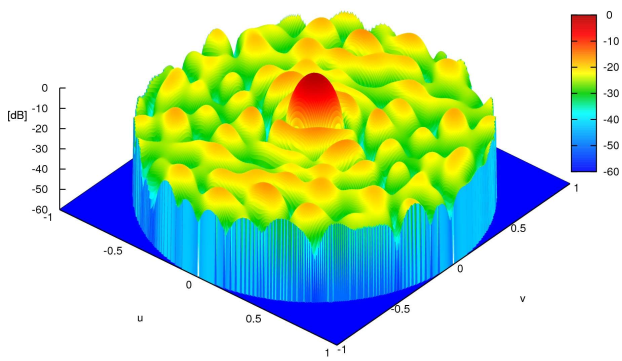


**Fig.2 - Pattern**

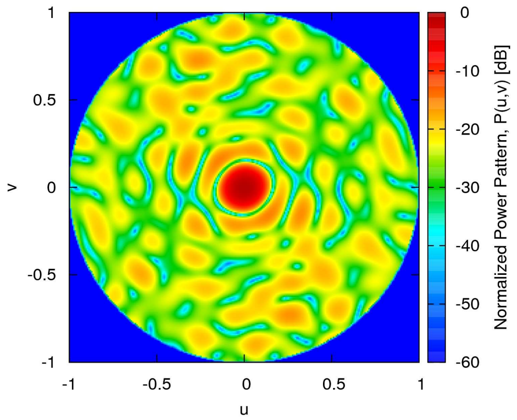


**Fig.3 - Pattern projection**

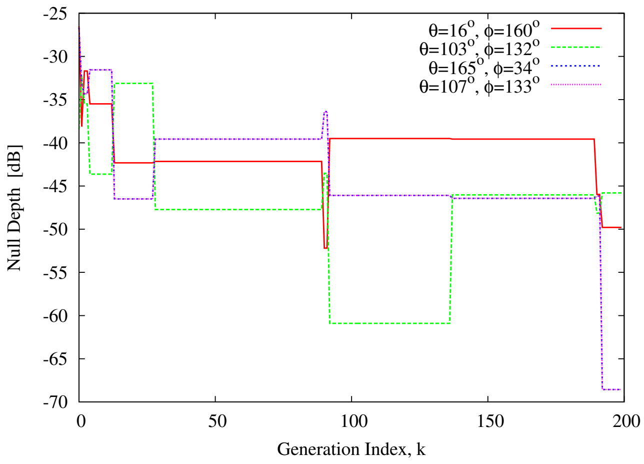


**Fig.4 - Nulls Depth 1**

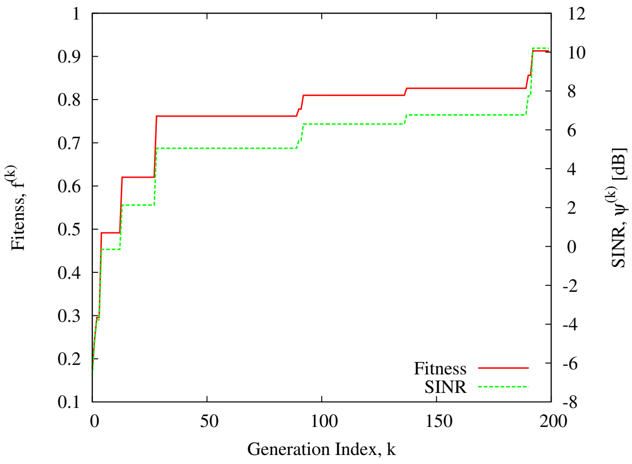


**Fig.5 - Fitness SINR**

SINR[dB]: 10.2

Null Depths[dB]: $[-49.79, -45.8, -68.56, -68.56]$

Number of Active Elements: 110

## TEST CASE - $N = 172$ -$Configuration = 7rings$ -$\eta \in [0.0, 1.0]$ - $N_I = 5$

### Goal

Maximization of the SINR using genetic algorithms (GA) to determine the optimal thinned ring array configuration, considering a time-varying scenario with 5 interferences.

### Test Case Description

- Number of Elements $N = 172$
- 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: $N_I = 5$
- Interference Direction Of Arrival: $\theta_1^i = 164°$, $\phi_1^i = 116°$
- Interference Direction Of Arrival: $\theta_2^i = 117°$, $\phi_2^i = 63°$
- Interference Direction Of Arrival: $\theta_3^i = 90°$, $\phi_3^i = 40°$
- Interference Direction Of Arrival: $\theta_4^i = 43°$, $\phi_4^i = 33°$
- Interference Direction Of Arrival: $\theta_5^i = 107°$, $\phi_5^i = 77°$

### Optimization Approach: GA

- Number of Variables: $X = 172$ $(\alpha_n,\ n = 1, ..., N)$
- Population: 86
- Crossover Probability: 0.9
- Mutation Probability: 0.01
- Number of Generations: 200
- Minimum Thinning Coefficient: 0.0
- Maximum Thinning Coefficient: 1.0

**GA - Multiple Interferences:** $\theta_1^i = 164°$, $\phi_1^i = 116°$; $\theta_2^i = 117°$, $\phi_2^i = 63°$; $\theta_3^i = 90°$, $\phi_3^i = 40°$; $\theta_4^i = 43°$, $\phi_4^i = 33°$; $\theta_5^i = 107°$, $\phi_5^i = 77°$

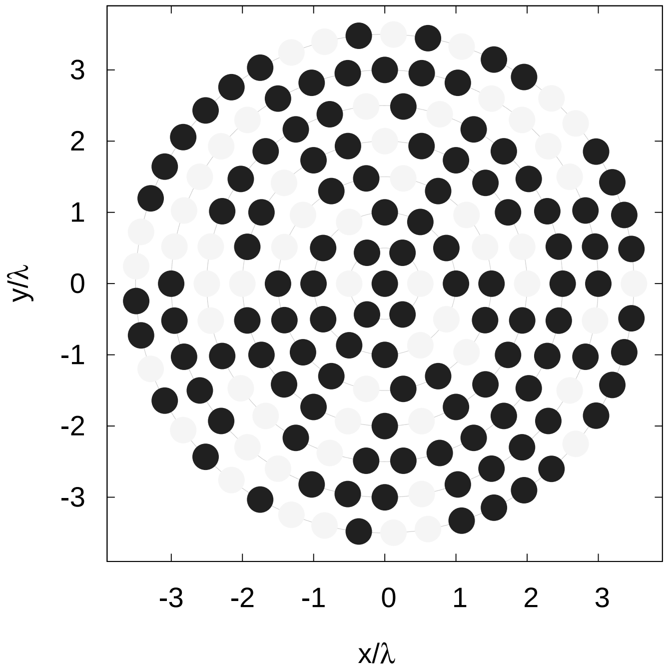


**Fig.1 - Thinning Configuration**

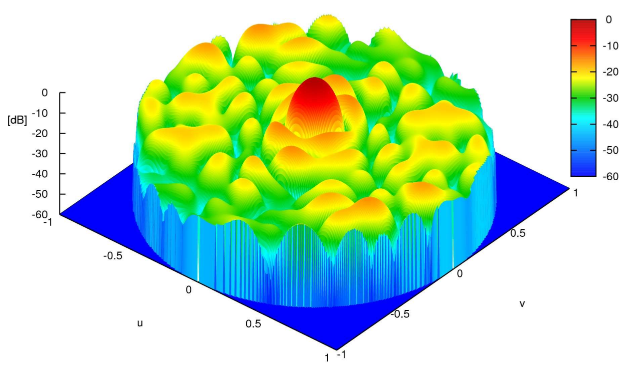


**Fig.2 - Pattern**

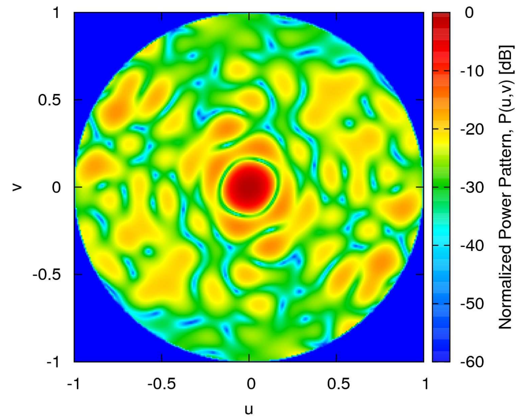


**Fig.3 - Pattern projection**

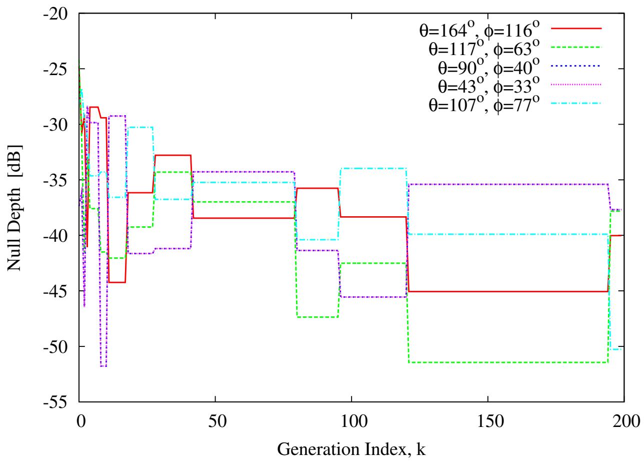


**Fig.4 - Nulls Depth 1**

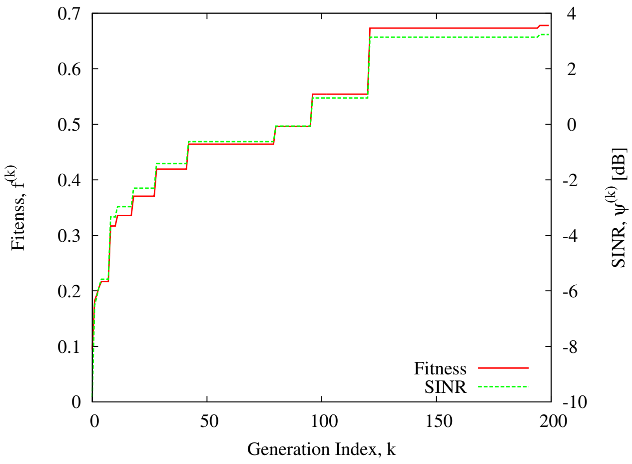


**Fig.5 - Fitness SINR**

SINR[dB]: 3.23

Null Depths[dB]: $[-40, -37.82, -37.68, -37.68, -50.26]$

Number of Active Elements:114

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

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