On the reconfigurabilty of Time-Modulated Linear Arrays subject to Failures - A statistical Analysis

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Abstract

In this report, the effectiveness and the robustness of a PSO-based optimization strategy aimed to reconfigure the on–off behavior of the undamaged array elements to provide a countermeasure to the nominal pattern corruption because of the failures is investigated. A statistical analysis is provided in order to show the dependency of the performance of the proposed technique not only on the number of failures, but also on the failure position within the array.

Numerical Results

TEST CASE 4.a - $N = 30$, Varying the Position of a Single Failure (Statistical Analysis)

Goal

Reconfigure the radiated pattern through a *PSO*-based optimization strategy according to the feature of the pattern before the failure occured to the *RF* switches.

Differences wrt previous test case

- Previous: Failures occured at the elements $n = 7$, 20, 28
- Current: Failures occured at a single element $n =\in \{1, 2, 3, ..., N\}$

Description

- Number of Elements $N = 30$
- Elements Spacing: $d = 0.7\lambda$
- Static Array Excitations: Uniform, $I_n = 1$, $n = 1$, $, N$
- Averaged Time-Modulated Array Excitations: Optimized to synthesize a pattern with $SLL = -20\,dB$
- Failure occured at a single element $n =\in \{1, 2, 3, ..., N\}$

Optimization Approach: PSO [1]

- Number of Variables: $X = 30$ (τ_n, $n = 1, ..., N$)
- Number of Particles: $S = N$
- Number of Iterations: $M = 1000$
- Inertial Weight: $I_w = 0.4$
- Cost Function: SLL weight: $w_{SLL} = 100$, BW weight: $w_{BW} = 1$, SR weight: $w_{SR} = 1$

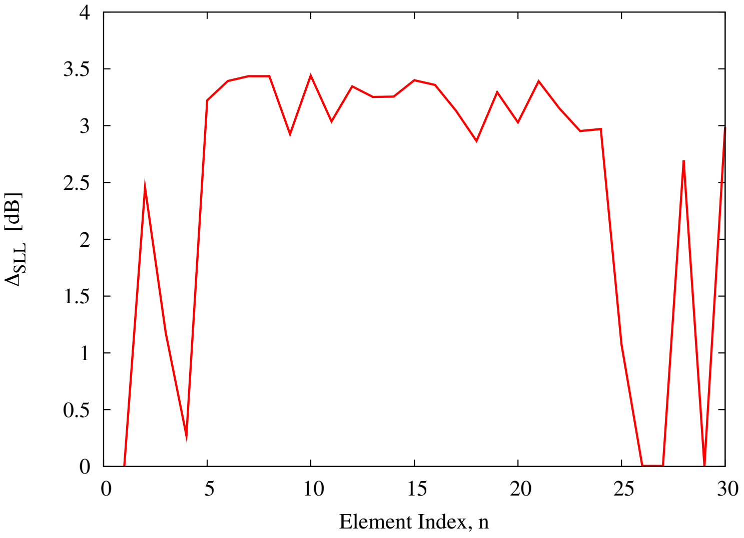

Fig. 115 - Delta SLL

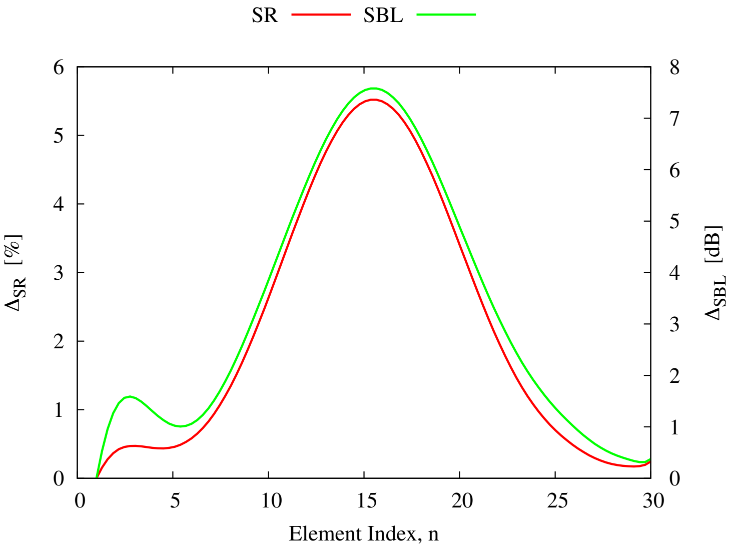

Fig. 116 - Delta SBL/SR

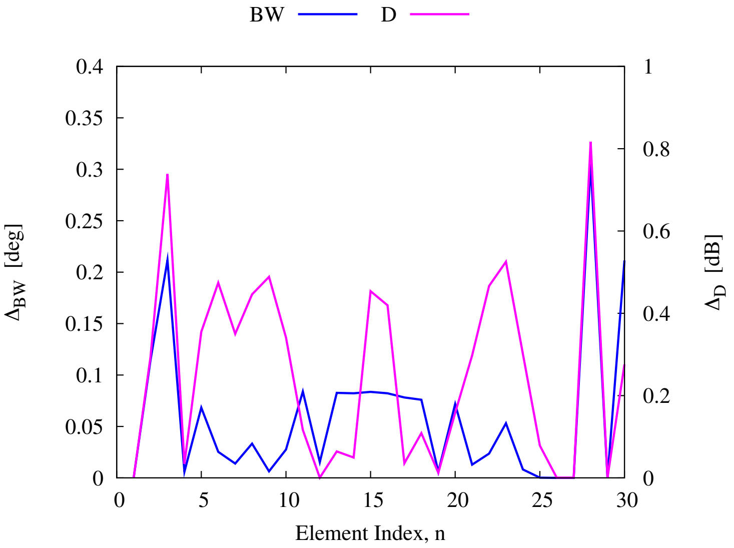

Fig. 117 - Delta BW/Directivity

Observations:

- Δ_i (where $i \in \{SLL, SR, SBL, BW, D\}$) is defined as the difference between the parameter (SLL, SR, SBL, BW or D) related to the compromised pattern and the parameter related to the optimized pattern. Figs. 115, 116 and 117 show the effects and the impact of the optimization process on the parameters, considering different position of the element with failure.

	$av\{SLL\,[dB]\}$	$var\{SLL\,[dB]\}$	$min\{SLL\,[dB]\}$	$max\{SLL\,[dB]\}$
$Compromised$	-17.44	1.45	-19.88	-16.51
$PSO - reconfigured$	-19.93	1.13×10^{-3}	-19.88	-19.97

Tab.XIV - SLL Statistics: average $av\{\cdot\}$, variance $var\{\cdot\}$, minimum $min\{\cdot\}$ and maximum $max\{\cdot\}$ of the sidelobe level expressed in dB ($SLL\,[dB]$)

	$av\{SR]\}$	$var\{SR\}$	$min\{SR\}$	$max\{SR\}$
$Compromised$	3.55	1.01×10^{-1}	2.42	3.82
$PSO - reconfigured$	5.71	6.03	3.39	10.71

Tab.XV - SR Statistics: average $av\{\cdot\}$, variance $var\{\cdot\}$, minimum $min\{\cdot\}$ and maximum $max\{\cdot\}$ of the sideband radiation (SR) expressed in percentage [%] on the total power

	$av\{SBL\,[dB]\}$	$var\{SBL\,[dB]\}$	$min\{SBL\,[dB]\}$	$max\{SBL\,[dB]\}$
$Compromised$	-28.95	1.03	-32.68	-28.54
$PSO - reconfigured$	-25.76	12.28	-29.60	-18.80

Tab.XVI - SBL Statistics: average $av\{\cdot\}$, variance $var\{\cdot\}$, minimum $min\{\cdot\}$ and maximum $max\{\cdot\}$ of the sideband level expressed in dB ($SBL\,[dB]$)

	$av\{BW\,[deg]\}$	$var\{BW\,[deg]\}$	$min\{BW\,[deg]\}$	$max\{BW\,[deg]\}$
$Compromised$	2.84	4.27×10^{-3}	2.77	3.05
$PSO - reconfigured$	2.83	1.98×10^{-3}	2.69	2.88

Tab.XVII - BW Statistics: average $av\{\cdot\}$, variance $var\{\cdot\}$, minimum $min\{\cdot\}$ and maximum $max\{\cdot\}$ of the beamwidth expressed in degrees ($BW\,[deg]$)

	$av\{D\,[dB]\}$	$var\{D\,[dB]\}$	$min\{D\,[dB]\}$	$max\{D\,[dB]\}$
$Compromised$	13.71	3.06×10^{-2}	13.55	14.06
$PSO - reconfigured$	13.90	1.05×10^{-1}	13.17	14.59

Tab.XVIII - Directivity Statistics: average $av\{\cdot\}$, variance $var\{\cdot\}$, minimum $min\{\cdot\}$ and maximum $max\{\cdot\}$ of the directivity expressed in dB ($D\,[dB]$)

TEST CASE 4.b - $N = 32$, Varying the Position of a Single Failure (Statistical Analysis)

Goal

Reconfigure the radiated pattern through a PSO-based optimization strategy according to the feature of the pattern before the failure occured to the RF switches.

Differences wrt previous test case

- Previous: Number of Elements $N = 30$, Elements Spacing: $d = 0.7\lambda$, Averaged Time-Modulated Array Excitations: Optimized to synthesize a pattern with $SLL = -20\,dB$
- Current: Number of Elements $N = 32$, Elements Spacing: $d = 0.5\lambda$, Averaged Time-Modulated Array Excitations: *Dolph-Chebyshev*, $SLL = -30\,dB$, $BW = 3.88\,deg$

Description

- Number of Elements $N = 32$
- Elements Spacing: $d = 0.5\lambda$
- Static Array Excitations: Uniform, $I_n = 1,\ \ n = 1,\ \ , N$
- Averaged Time-Modulated Array Excitations: *Dolph-Chebyshev*, $SLL = -30\,dB$, $BW = 3.88\,deg$
- Failure occured at a single element $n = \in \{1, 2, 3, ..., N\}$

Optimization Approach: PSO [1]

- Number of Variables: $X = 32$ (τ_n, $n = 1, ..., N$)
- Number of Particles: $S = N$
- Number of Iterations: $M = 1000$
- Inertial Weight: $I_w = 0.4$
- Cost Function: SLL weight: $w_{SLL} = 100$, BW weight: $w_{BW} = 1$, SR weight: $w_{SR} = 1$

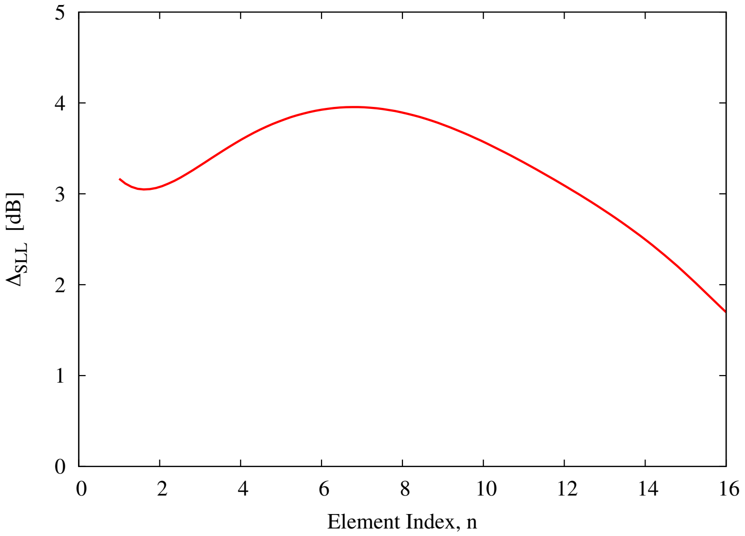

Fig. 118 - Delta SLL

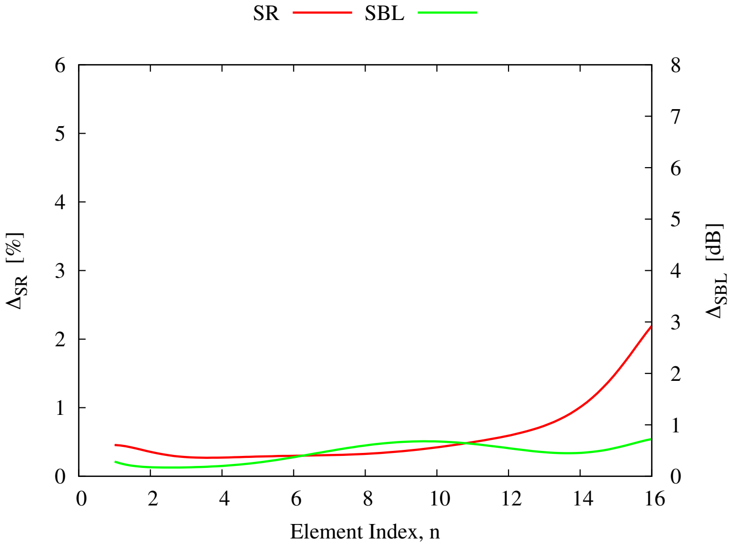

Fig. 119 - Delta SBL/SR

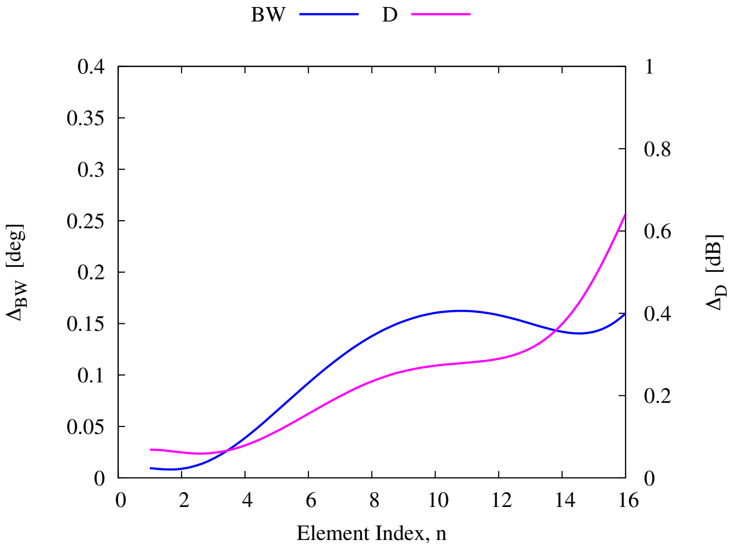

Fig. 120 - Delta BW/Directivity

Notes:

- Δ_i (where $i \in \{SLL, SR, SBL, BW, D\}$) is defined as the difference between the parameter (SLL, SR, SBL, BW or D) related to the compromised pattern and the parameter related to the optimized pattern. Figs. 118, 119 and 120 show the effects and the impact of the optimization process on the parameters, considering different position of the element with failure.
- Half elements ($N/2 = 16$) of the array have been taken into account because of simmetry reasons.

	$av\{SLL\,[dB]\}$	$var\{SLL\,[dB]\}$	$min\{SLL\,[dB]\}$	$max\{SLL\,[dB]\}$
$Compromised$	-23.94	3.44	-27.11	-21.66
$PSO-reconfigured$	-27.22	5.08	-29.86	-23.36

Tab.XIX - SLL Statistics: average $av\{\cdot\}$, variance $var\{\cdot\}$, minimum $min\{\cdot\}$ and maximum $max\{\cdot\}$ of the sidelobe level expressed in dB ($SLL\,[dB]$)

	$av\{SR]\}$	$var\{SR\}$	$min\{SR\}$	$max\{SR\}$
$Compromised$	23.96	0.47	23.26	25.13
$PSO-reconfigured$	24.20	1.36	22.91	27.32

Tab.XX - SR Statistics: average $av\{\cdot\}$, variance $var\{\cdot\}$, minimum $min\{\cdot\}$ and maximum $max\{\cdot\}$ of the sideband radiation (SR) expressed in percentage [%] on the total power

	$av\{SBL\,[dB]\}$	$var\{SBL\,[dB]\}$	$min\{SBL\,[dB]\}$	$max\{SBL\,[dB]\}$
$Compromised$	-12.29	8.27×10^{-2}	-12.63	-11.88
$PSO-reconfigured$	-12.45	3.76×10^{-1}	-13.31	-11.16

Tab.XXI - SBL Statistics: average $av\{\cdot\}$, variance $var\{\cdot\}$, minimum $min\{\cdot\}$ and maximum $max\{\cdot\}$ of the sideband level expressed in dB ($SBL\,[dB]$)

	$av\{BW\,[deg]\}$	$var\{BW\,[deg]\}$	$min\{BW\,[deg]\}$	$max\{BW\,[deg]\}$
$Compromised$	3.88	4.93×10^{-3}	3.78	4.02
$PSO-reconfigured$	3.99	2.42×10^{-3}	3.91	4.07

Tab.XXII - BW Statistics: average $av\{\cdot\}$, variance $var\{\cdot\}$, minimum $min\{\cdot\}$ and maximum $max\{\cdot\}$ of the beamwidth expressed in degrees ($BW\,[deg]$)

	$av\{D\,[dB]\}$	$var\{D\,[dB]\}$	$min\{D\,[dB]\}$	$max\{D\,[dB]\}$
$Compromised$	11.39	1.10×10^{-2}	11.25	11.57
$PSO-reconfigured$	11.71	7.50×10^{-2}	10.61	11.64

Tab.XXIII - Directivity Statistics: average $av\{\cdot\}$, variance $var\{\cdot\}$, minimum $min\{\cdot\}$ and maximum $max\{\cdot\}$ of the directivity expressed in dB ($D\,[dB]$)

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