A Novel Strategy to Derive Pareto-Optimal Tiling Configurations in Phased Arrays

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Contents

1 Introduction

This work presents an innovative tiling optimization strategy for arbitrary orthogonal-polygon shaped apertures. An exhaustive search approach, together with a multi-objective strategy, has been used in order to obtain optimal tiling configurations, jointly optimizing two different pattern features of interest. A simple example validating the proposed method has been finally reported.

2 Numerical Results

2.1 Orthogonal Polygon #1

Array Analysis Parameters:

- Total Number of Elements: $P = 48$
- Spacing: $d = \lambda/2$
- Number of Samples along u: 512
- Number of Samples along v: 512
- Steering θ Direction: $\theta_s = 0$
- Steering ϕ Direction: $\phi_s = 0$

Tiling Parameters:

- Total Number of Configurations: $\Gamma = 9531$
- Number of Inner Lattice Points: $N_{inn} = 30$

2.1.1 ETM-MOP - CP Reference Excitations, Asymmetric Mask, SLL = -25 [dB] - SLL vs {D, HPBW}

Reference Fully-Populated Array:

- Main Lobe Window Width along u: $MW_u = 0.35$ [u]
- Main Lobe Window Width along v: $MW_v = 0.35$ [v]
- Side Lobe levels: $SLL_1 = -18$ [dB], $SLL_2 = -20$ [dB], $SLL_3 = -25$ [dB]

Cost Function:

- $OBJ^{(1)} = SLL$
- $OBJ^{(2)} = HPBW_{AZ}$
- $OBJ^{(3)} = HPBW_{EL}$
- $OBJ^{(4)} = D$

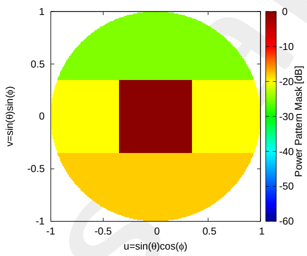


Figure 1: The power pattern mask used for the reference tapering optimization with CP.

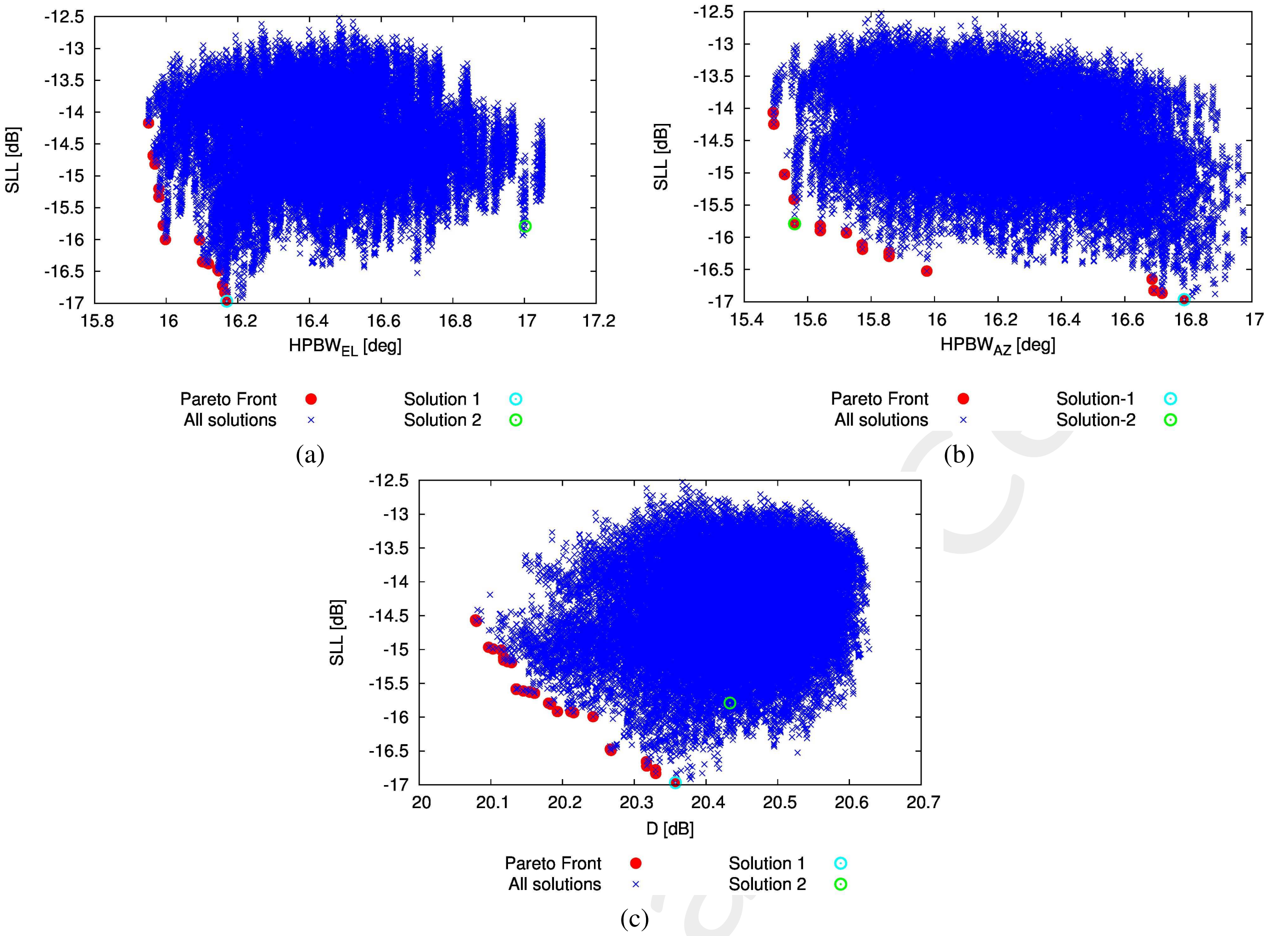


Figure 2: Pareto front of the ETM soutions considering: $OBJ^{(1)} = SLL$, $OBJ^{(2)} = HPBW_{AZ}$ (a), $OBJ^{(1)} = SLL$, $OBJ^{(3)} = HPBW_{EL}$(b), $OBJ^{(1)} = SLL$, $OBJ^{(4)} = D$ (c).

	SLL [dB]	D [dBi]	$HPBW_{az}$ [deg]	$HPBW_{el}$ [deg]	$\Psi(T)$
$Reference$	-18.70	21.00	17.09	16.76	$-$
$Solution-1$	-17.52	21.03	16.82	16.59	$-$
$Solution-1$	-16.47	21.00	16.72	16.49	$-$

Table I: Pattern descriptors and fitness values for the presented solutions.

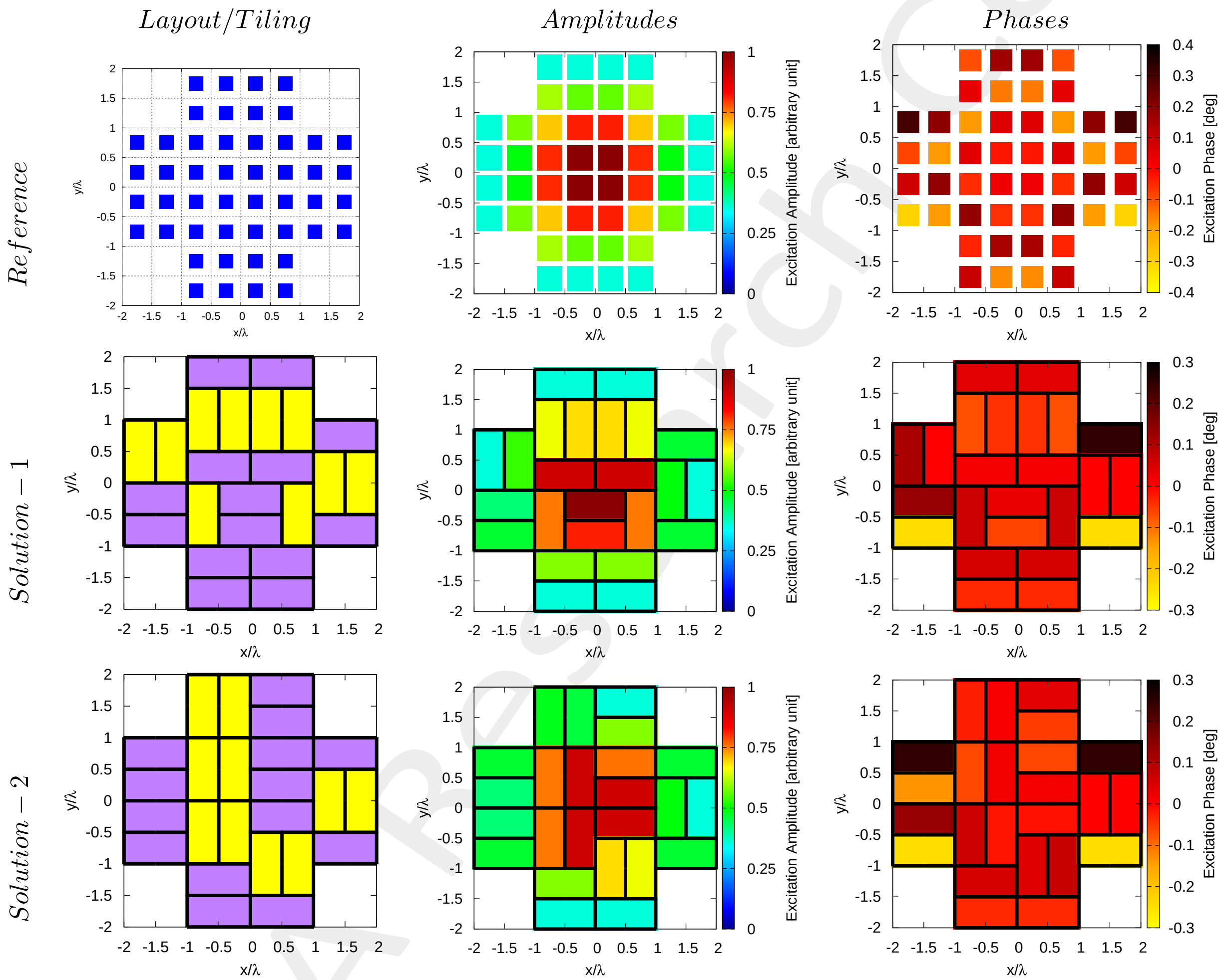


Figure 3: Tiling Configurations/Excitations.

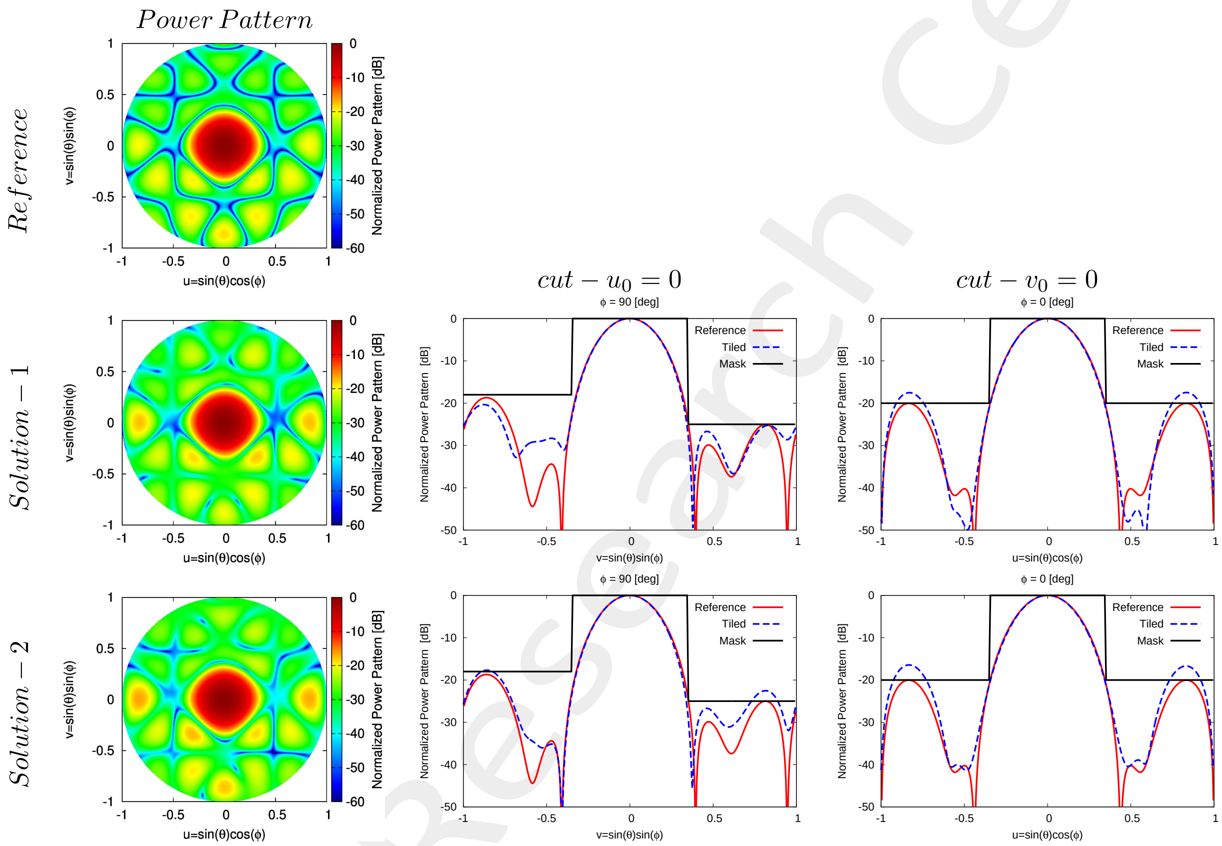


Figure 4: Power Patterns.

OUTCOME:

- Solution-1 exhibits the best SLL
- $HPBW_{AZ}$ $HPBW_{EL}$ and D shows very low variation range among all solutions

2.1.2 ETM-MOP - CP Reference Excitations, Symmetric Mask, SLL = -25 [dB] - SLL vs {D, HPBW}

Reference Fully-Populated Array:

- Number of Samples along u: 512
- Number of Samples along v: 512
- Steering θ Direction: $\theta_s = 0$
- Steering ϕ Direction: $\phi_s = 0$
- Main Lobe Window Width along u: $MW_u = 0.35$ [u]
- Main Lobe Window Width along v: $MW_v = 0.35$ [v]
- Side Lobe levels: $SLL_1 = -25$ [dB]

Cost Function:

- $OBJ^{(1)} = SLL$
- $OBJ^{(2)} = HPBW_{AZ}$
- $OBJ^{(3)} = HPBW_{EL}$
- $OBJ^{(4)} = D$

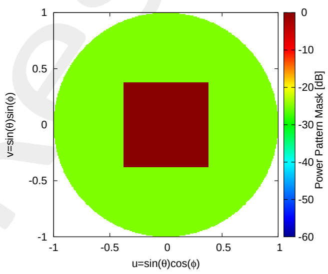


Figure 5: The power pattern mask used for the reference tapering optimization with CP.

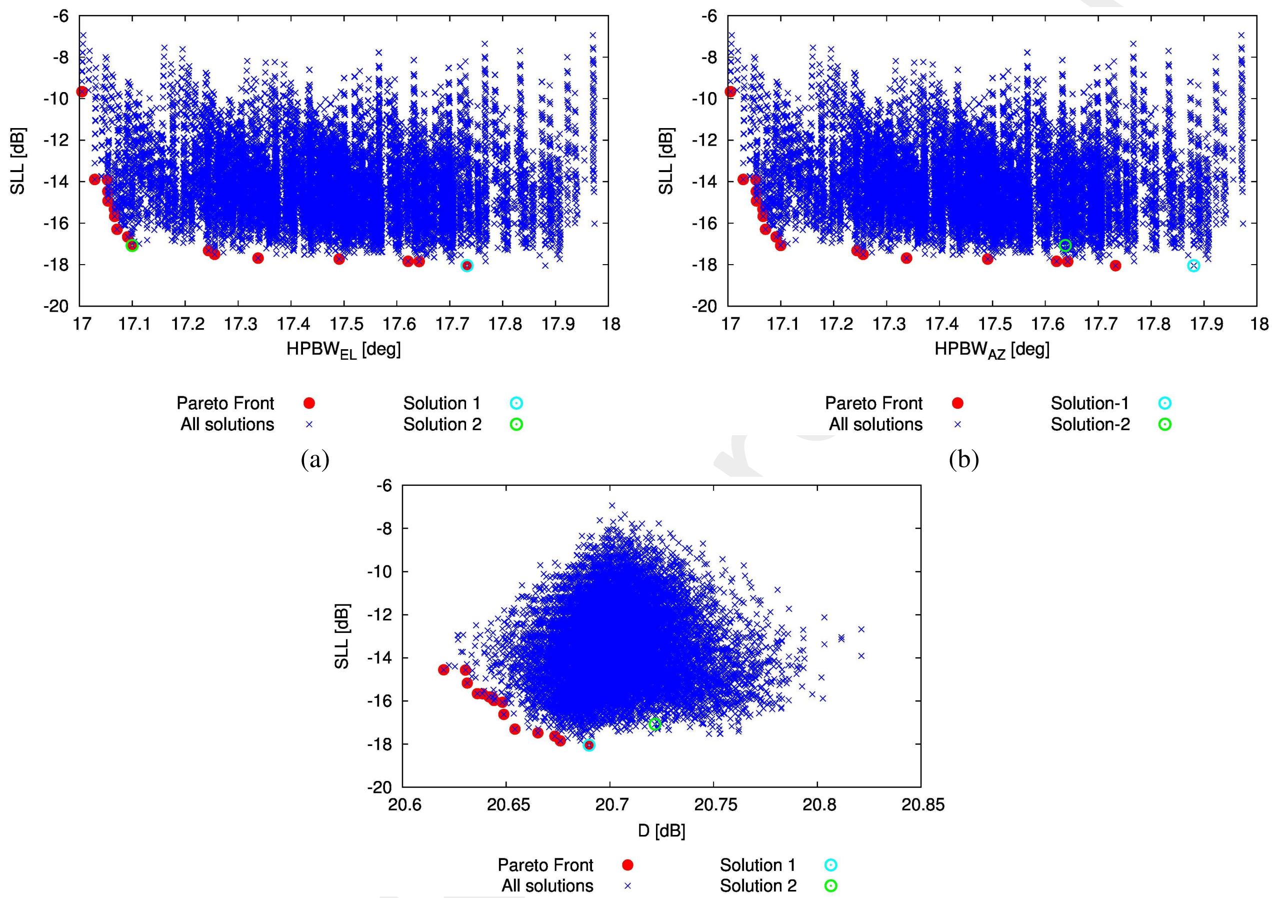
Tiling Parameters:

- Tile: Domino
- Number of Elements in each Tile: $N_T = 2$
- Total Number of Configurations: $\Gamma = 9531$
- Number of Inner Lattice Points: $N_{inn} = 30$

Cost Function:

- $OBJ^{(1)} = SLL$
- $OBJ^{(2)} = HPBW_{AZ}$
- $OBJ^{(3)} = HPBW_{EL}$
- $OBJ^{(4)} = D$

RESULTS



(c)

Figure 6: Pareto front of the ETM soutions considering: $OBJ^{(1)} = SLL$, $OBJ^{(2)} = HPBW_{AZ}$ (a), $OBJ^{(1)} = SLL$, $OBJ^{(3)} = HPBW_{EL}$(b), $OBJ^{(1)} = SLL$, $OBJ^{(4)} = D$ (c).

	SLL [dB]	D [dBi]	$HPBW_{az}$ [deg]	$HPBW_{el}$ [deg]	$\Psi(T)$
$Reference$	-25.00	20.69	17.97	17.97	–
$Solution-1$	-21.61	20.69	17.88	17.73	–
$Solution-2$	-18.76	20.72	17.64	17.10	–

Table II: Pattern descriptors and fitness values for the presented solutions.

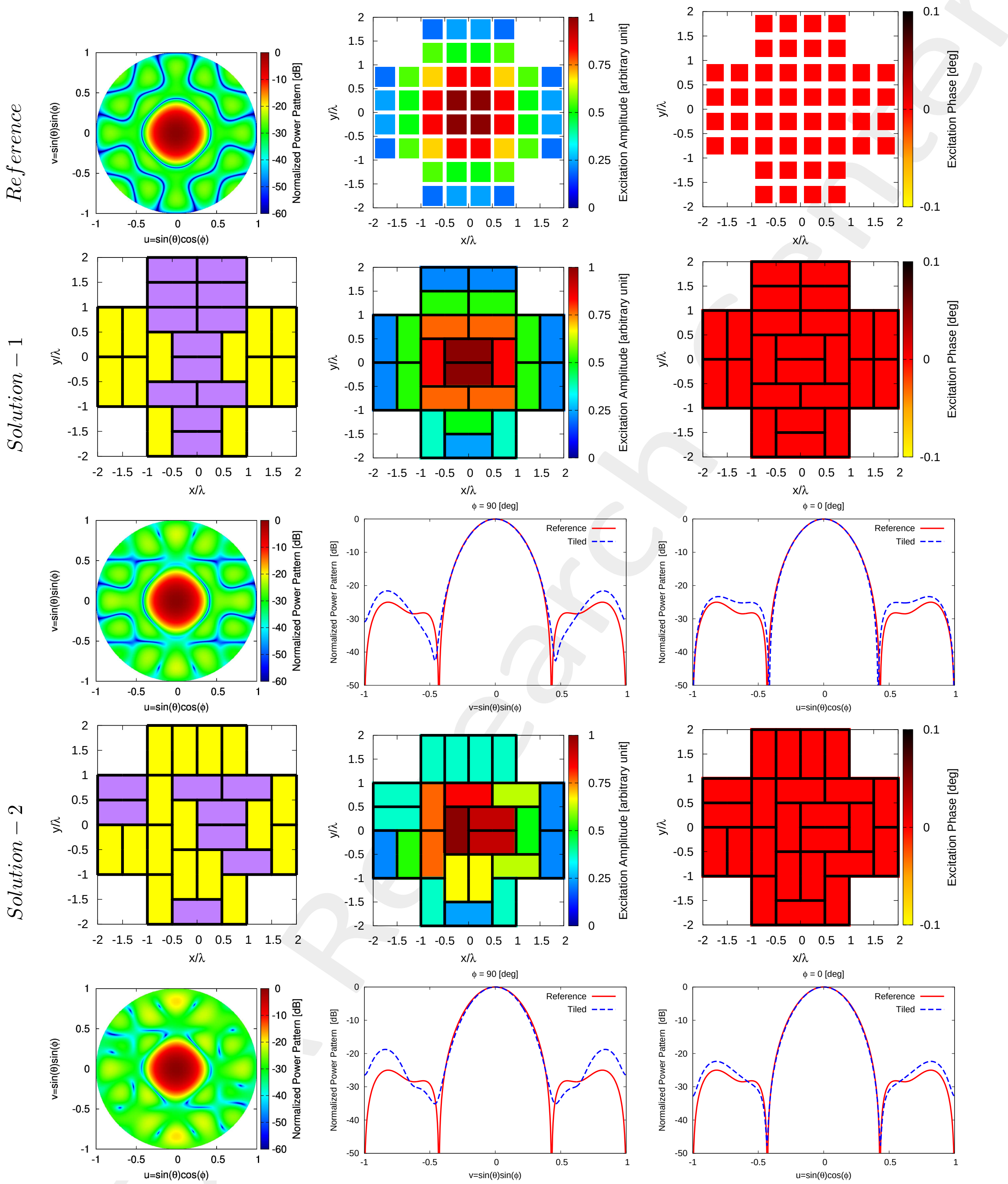


Figure 7: Tiling Configurations/Excitations.

OUTCOME:

- Solution-1 minimize the SLL with a maximum difference of 3.4 [dB] with respect to the reference.
- Solution-2 is the best compromise among the SLL and the $HPBW_{EL}$. A reduction of $0.63B$ [deg] is obtained for the $HPBW_{EL}$ parameter, at the cost of 2.85 [dB] for the SLL parameter, with respect to Solution-1.

2.1.3 ETM-MOP - CP Reference Excitations, Symmetric Mask, SLL = -25 [dB] - Mask Matching vs {SLL, D, HPBW}

Reference Fully-Populated Array:

- Number of Samples along u: 512 $-2 < u < 2$
- Number of Samples along v: 512 $-2 < v < 2$
- Steering θ Direction: $\theta_s = 0$
- Steering ϕ Direction: $\phi_s = 0$
- Main Lobe Window Width along u: $MW_u = 0.35$ [u]
- Main Lobe Window Width along v: $MW_v = 0.35$ [v]
- Side Lobe levels: $SLL_1 = -25$ [dB]

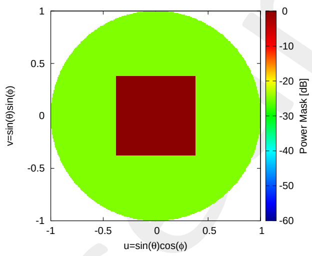


Figure 8: The power pattern mask used for the reference tapering optimization with CP.

Cost Function:

- $OBJ^{(1)} = SLL$
- $OBJ^{(2)} = HPBW_{AZ}$
- $OBJ^{(3)} = HPBW_{EL}$
- $OBJ^{(4)} = D$
- $OBJ^{(5)} = \int_{-1}^{1}\int_{-1}^{1} \left[M\left(u,v\right) - P\left(u,v;\underline{C}\right)\right]\mathcal{H}\left[P\left(u,v;\underline{C}\right) - M\left(u,v\right)\right] dudv$

RESULTS

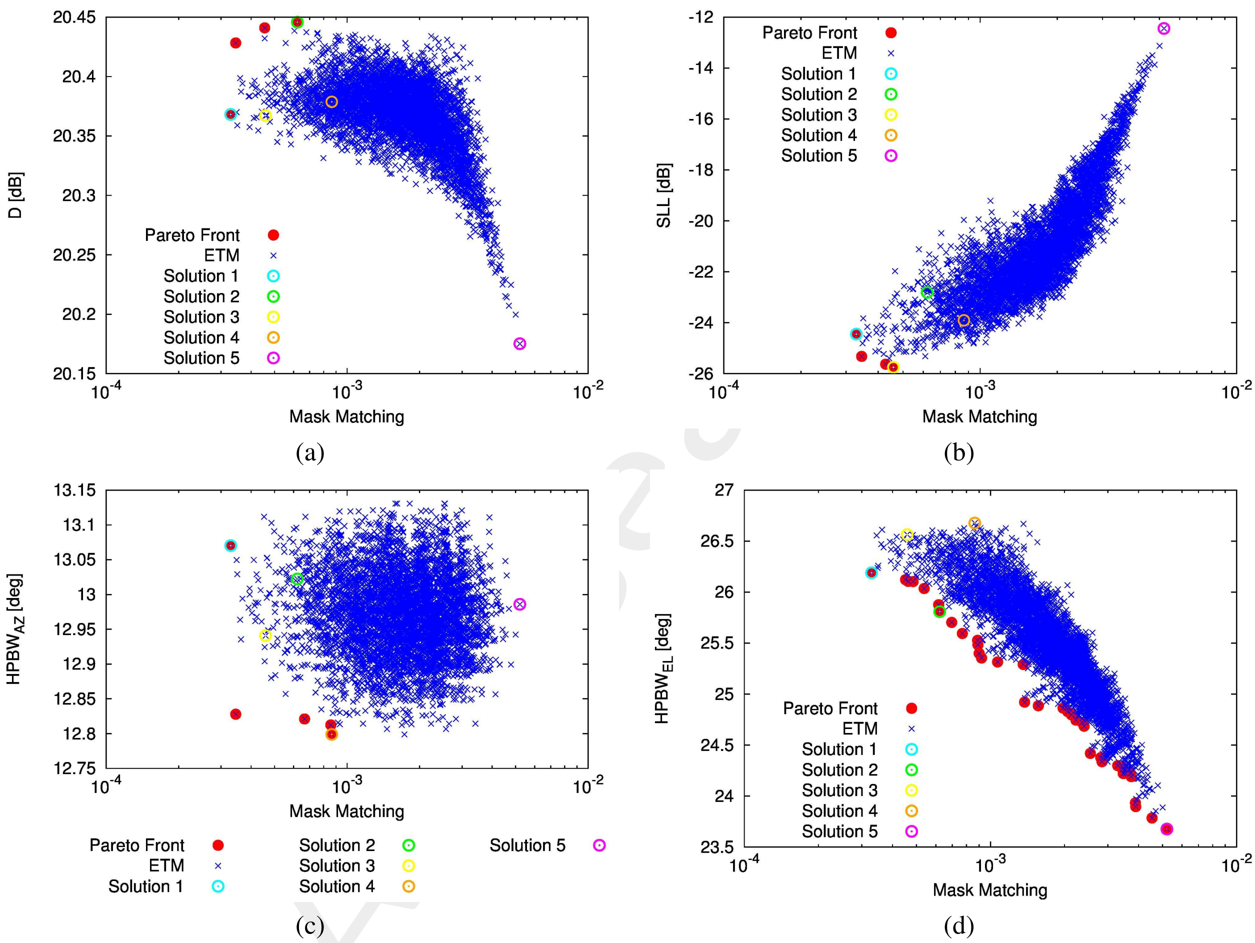


Figure 9: Pareto front of the ETM soutions.

	$Solution\,ID$	SLL [dB]	D [dBi]	$HPBW_{az}$ [deg]	$HPBW_{el}$ [deg]	$Mask\,Matching$
$Reference$	$-$	-25.00	20.69	17.97	17.97	0.00
$Solution-1$	3754	-23.74	20.69	17.90	17.85	3.50×10^{-5}
$Solution-2$	95892	-19.10	20.82	17.05	17.49	1.24×10^{-3}
$Solution-3$	2522	-23.84	20.69	17.91	17.84	4.20×10^{-5}
$Solution-4$	96963	-15.25	20.75	17.00	17.49	2.61×10^{-3}
$Solution-5$	84979	-15.25	20.75	17.49	17.00	2.61×10^{-3}

Table III: Pattern descriptors and fitness values for the presented solutions.

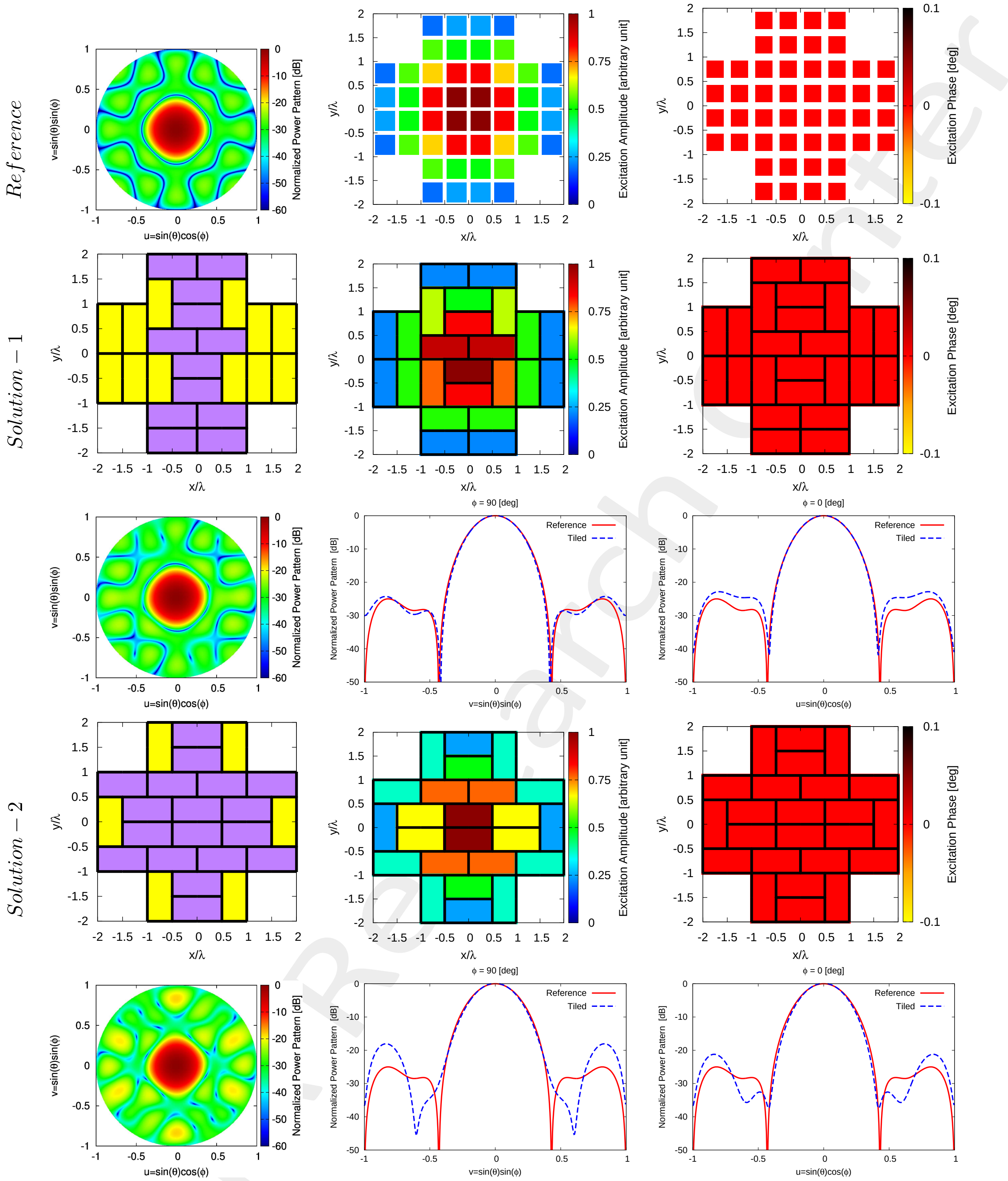


Figure 10: Power Patterns.

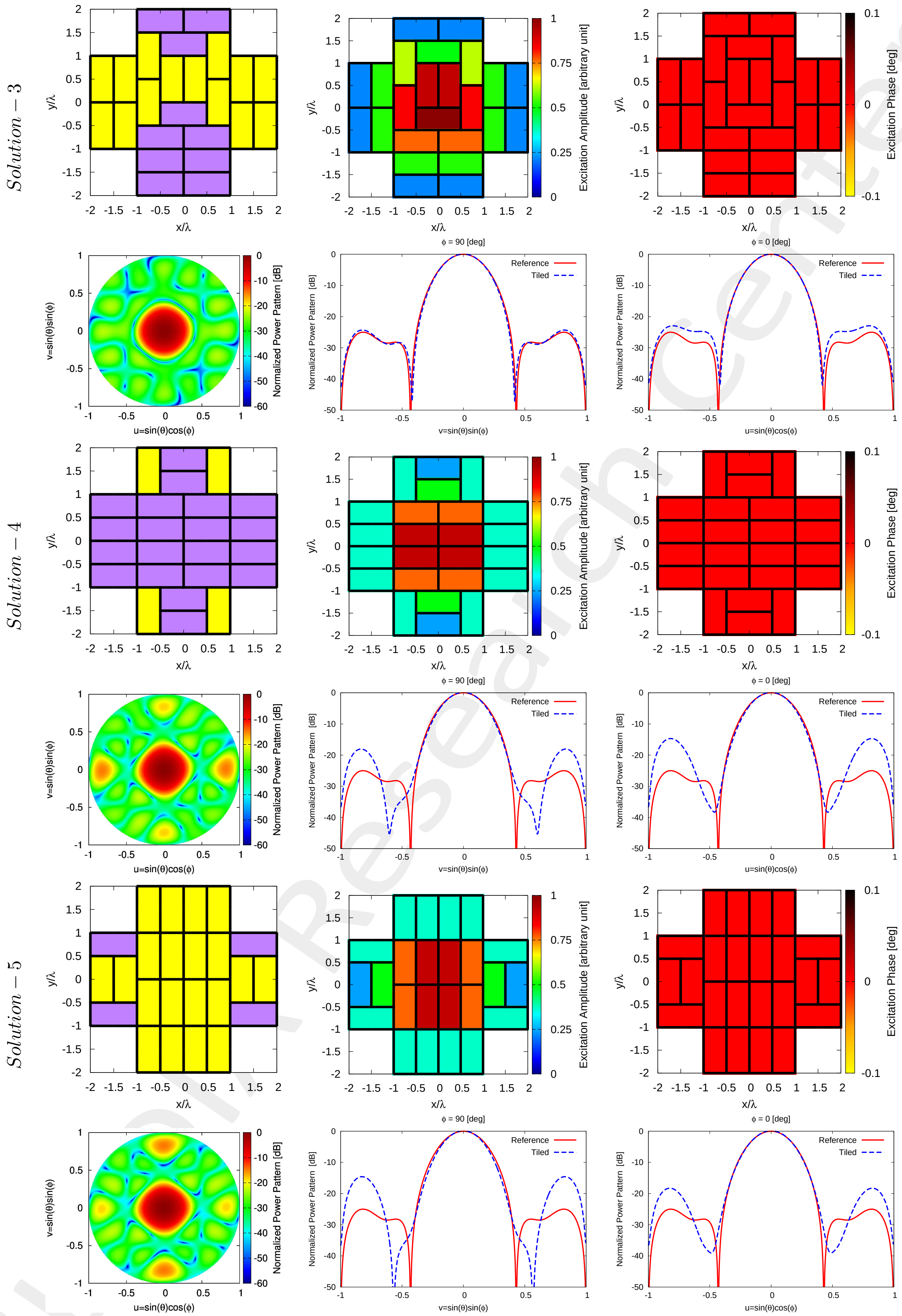


Figure 11: Power Patterns.

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

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