Netherlands Institute for Radio Astronomy

Tile separation study for EMBRACE-like vivaldi dense array: polarimetry and sensitivity

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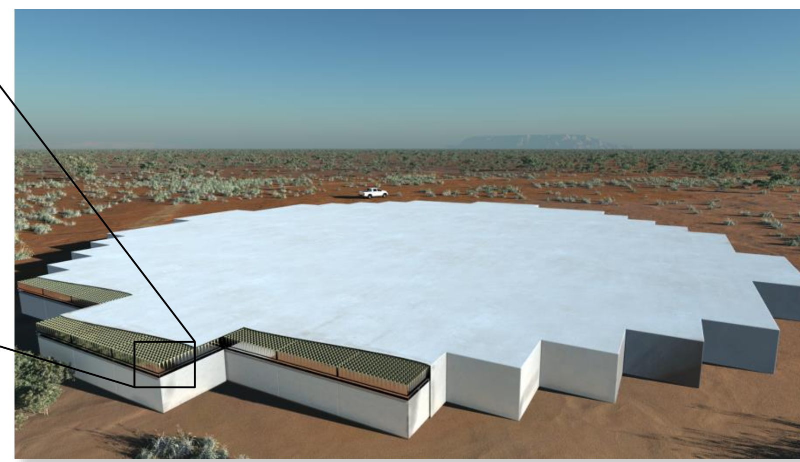
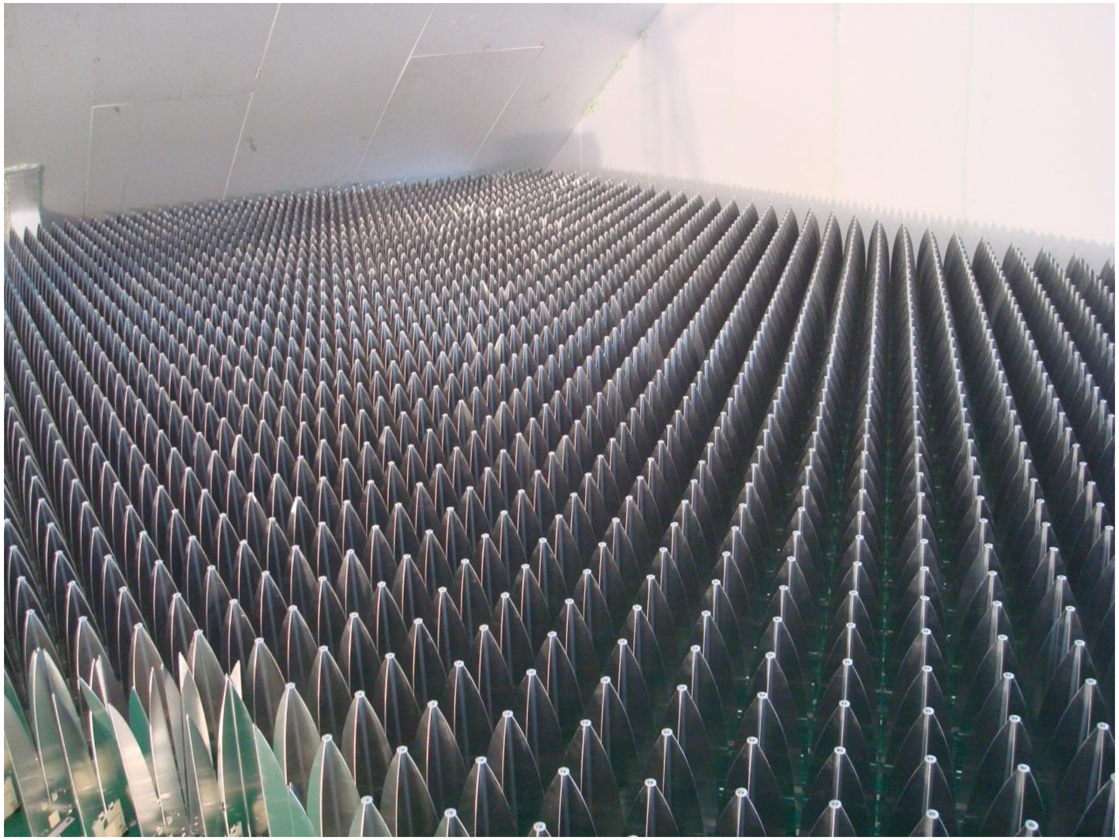
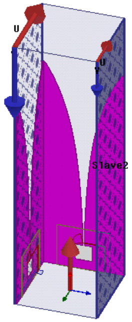
1st MIDPREP – 31 March '14



MFAA

Dense regular arrays



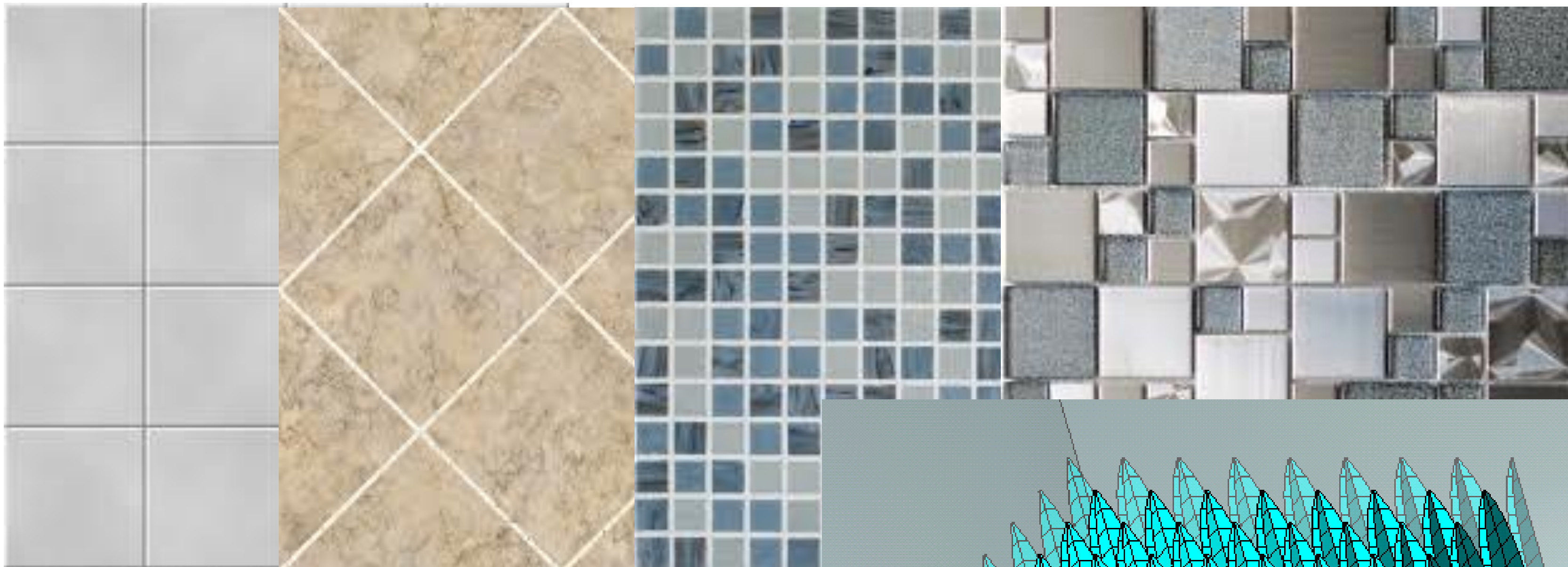


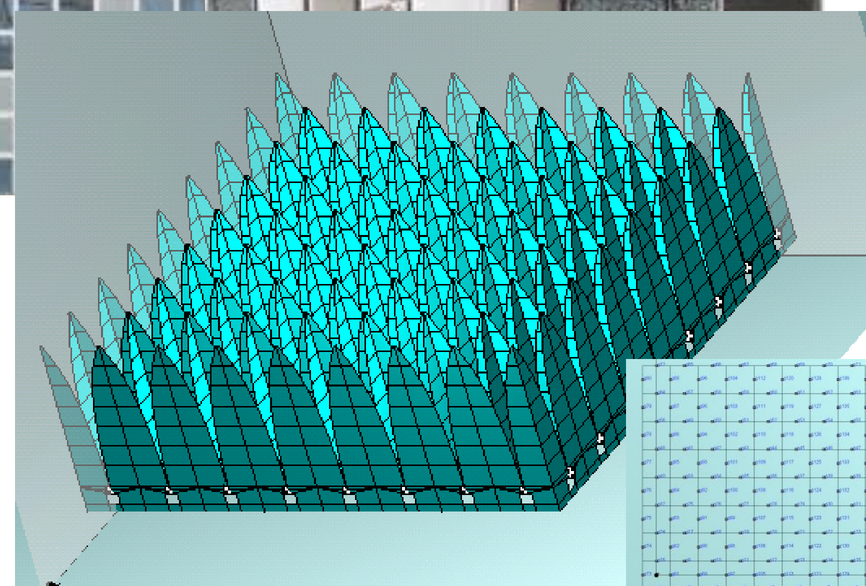
Infinite Array
+
Station Edge Effect

Finiteness of the array is an unavoidable

➡ Study the modular tiles edge effect

What is a tile??

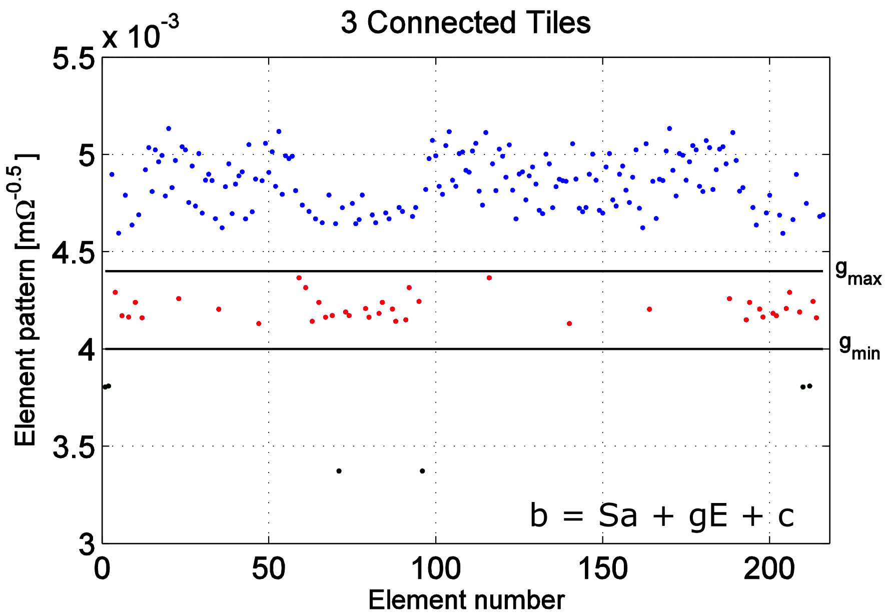




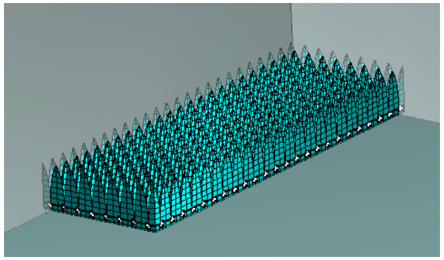
- Modular and regular
- Homogeneous performances

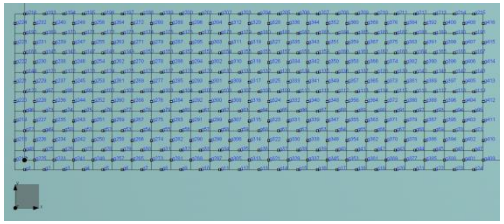
Station configuration

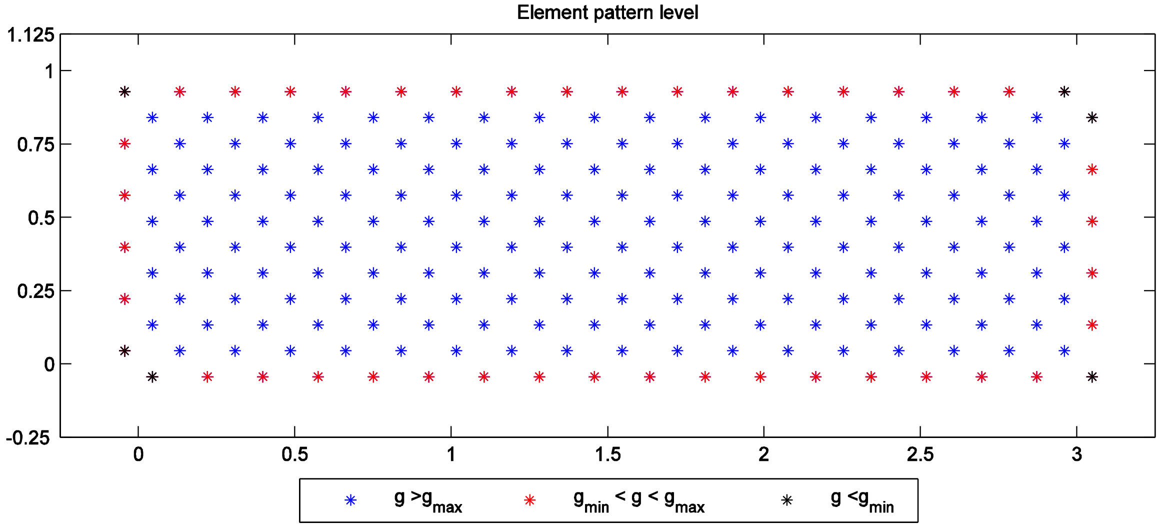
What is a tile?

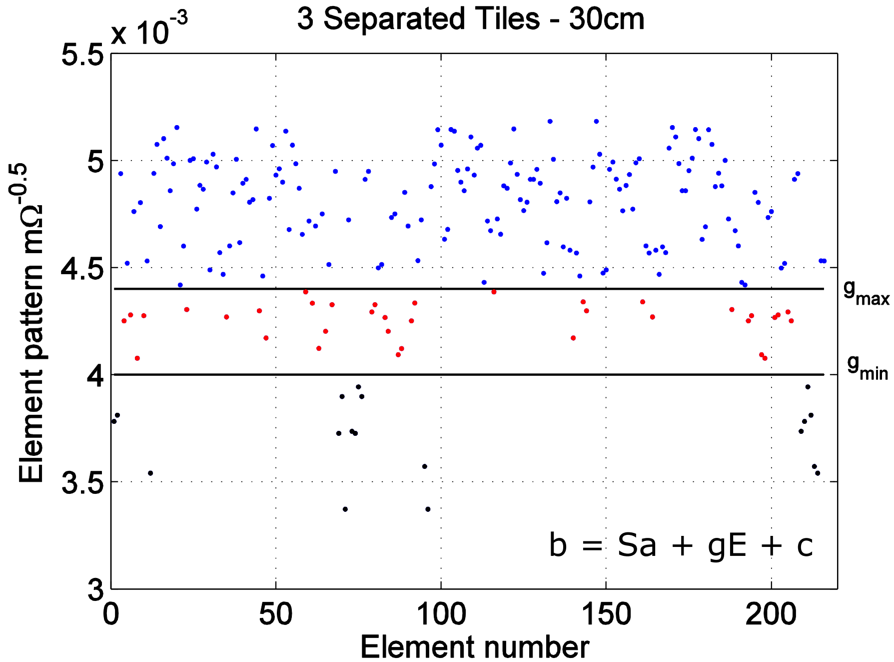


3 connected tiles

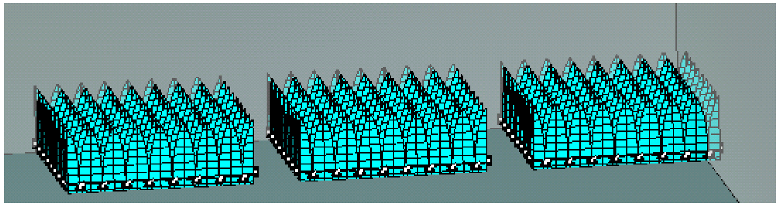


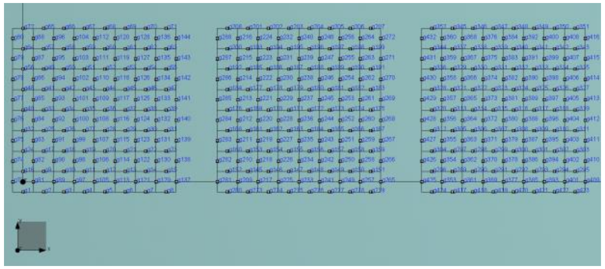


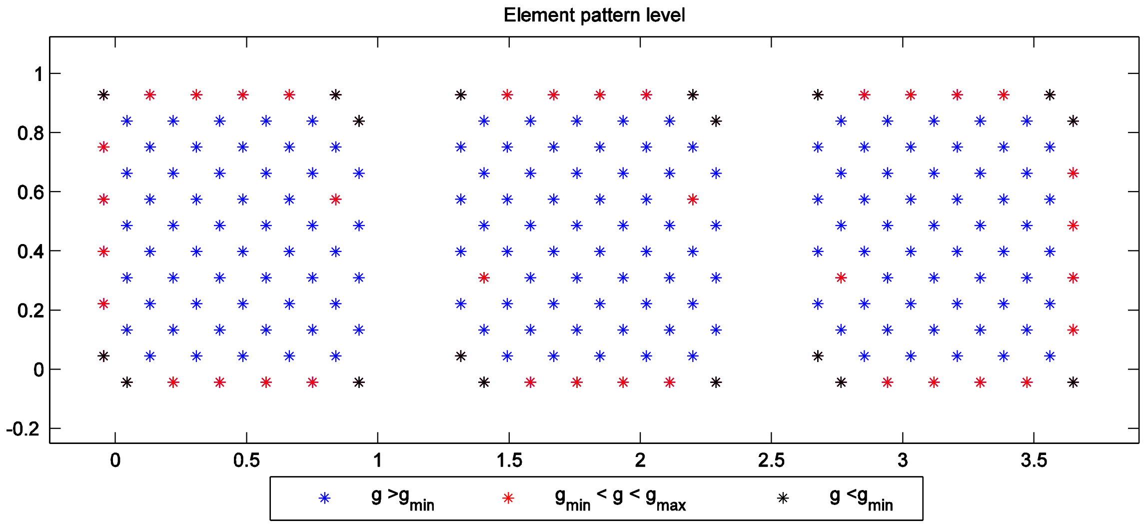




3 separated tiles

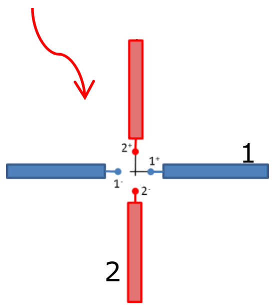






Polarization Discrimination Ratios for Jones Polarimeters

$$\mathbf{E}^{\text{inc}} = E_x\hat{x} + E_y\hat{y}$$



$$\begin{bmatrix} v_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} J_{1x} & J_{1y} \\ J_{2x} & J_{2y} \end{bmatrix} \begin{bmatrix} E_x \\ E_y \end{bmatrix}$$

Measured output

Transfer function to be inverted

Incident field

$$XPD_x = \frac{|J_{1x}|^2}{|J_{2x}|^2} \qquad XPI_1 = \frac{|J_{1x}|^2}{|J_{1y}|^2}$$

- Raw cross-polarization
- Definition dependent on the coordinate system

A new figure-of-merit for radio polarimeters

Intrinsic cross-polarization ratio

$$IXR = \left(\frac{\kappa(\mathbf{J})+1}{\kappa(\mathbf{J})-1}\right)^2$$

Related to the condition number of the Jones matrix

- Independent of the coordinate system
- Precision achievable inferring the input signal polarization state

$$\mathbf{e} = \mathbf{J}^{-1}\mathbf{f}$$

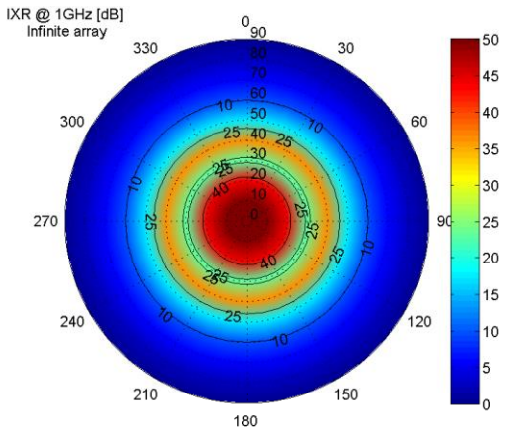
$$\frac{\|\Delta \mathbf{e}\|}{\|\mathbf{e}\|} \leq \left(1 + \frac{2}{\sqrt{IXR}} + \ldots\right)\left(\frac{\|\Delta \mathbf{J}\|}{\|\mathbf{J}\|} + \frac{\|\Delta \mathbf{f}\|}{\|\mathbf{f}\|}\right)$$

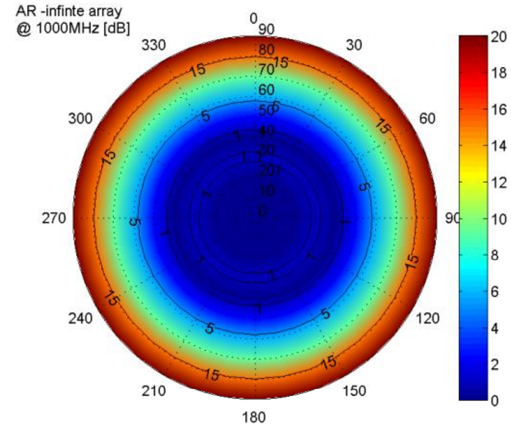
the total relative error of the fully calibrated polarimeter

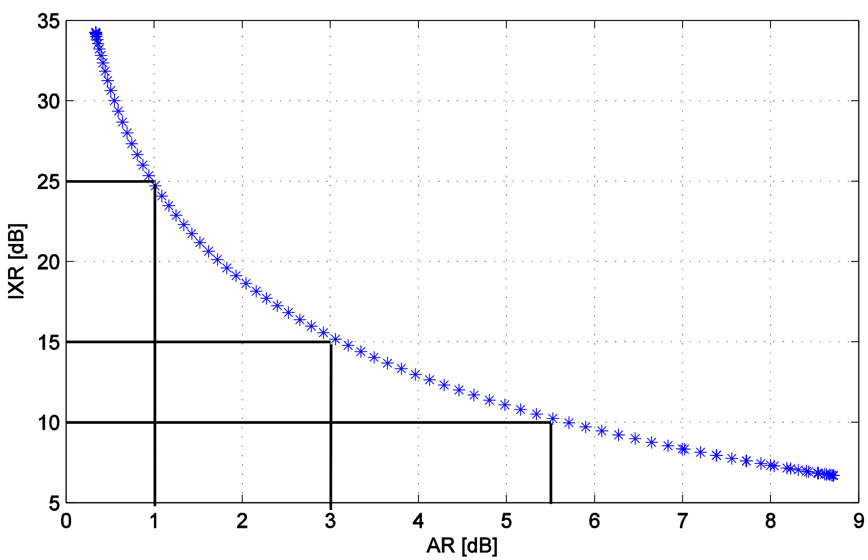
Better polarimetric design: isolation and channel symmetry

T. Carozzi and G. Woan, IEEE Trans. Antennas Propag, 2009

IXR and Axial Ratio



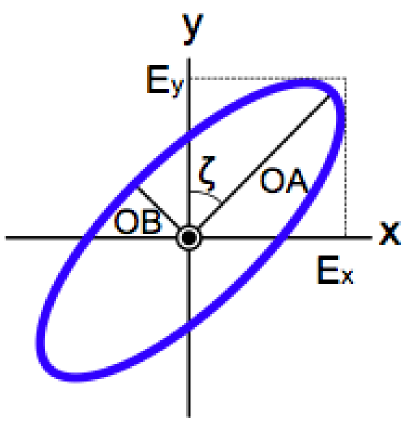




Intrinsic cross-polarization ratio

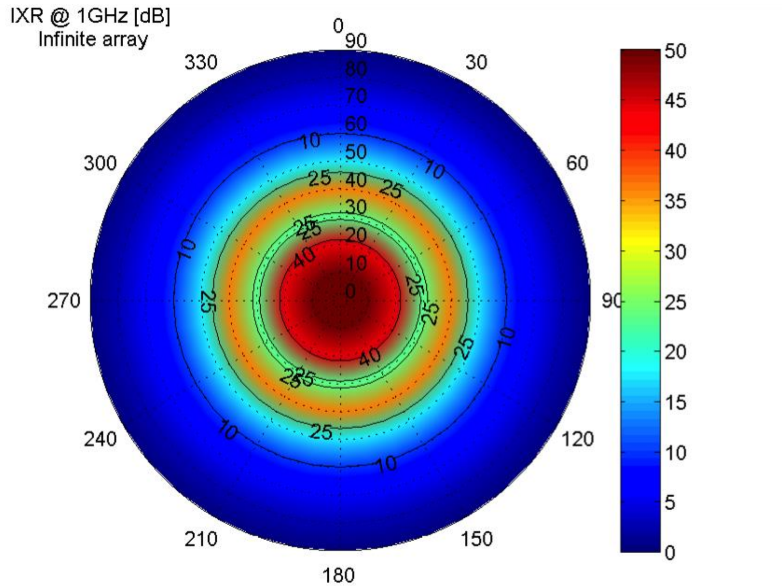
$$IXR = \left(\frac{\kappa(\mathbf{J})+1}{\kappa(\mathbf{J})-1} \right)^2$$

Axial ratio

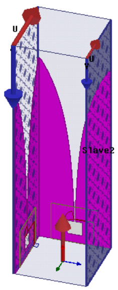


$$AR = \frac{\mathbf{OA}}{\mathbf{OB}} = \kappa(\mathbf{J})$$

Infinite Array as reference



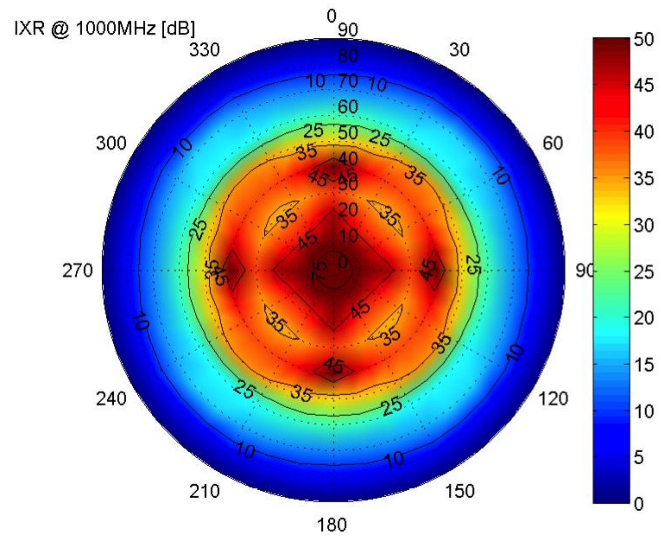
IXR levels:
10dB up to 60 degrees,
25 dB up to 45 degrees,
40 dB up to 20 degrees.

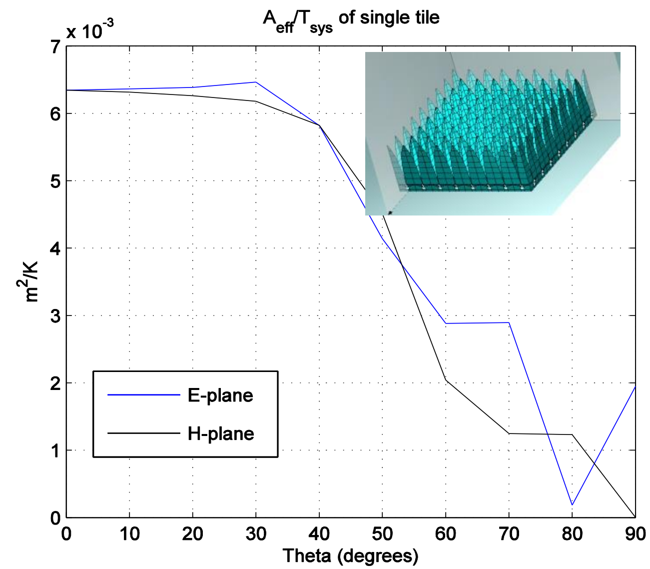


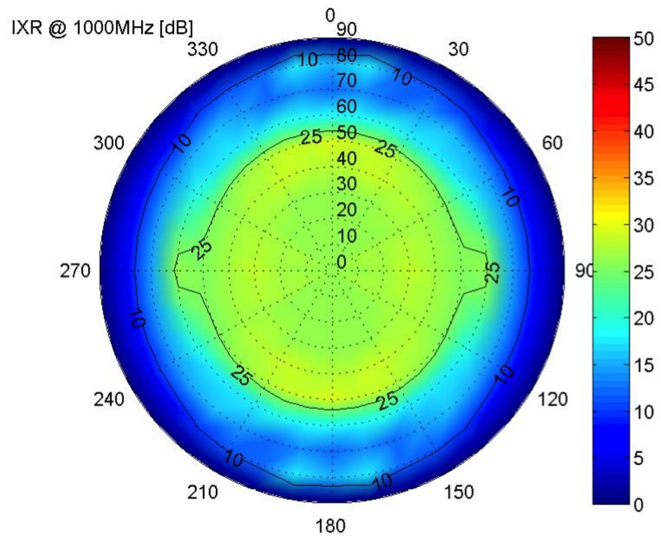
Analysis based on:

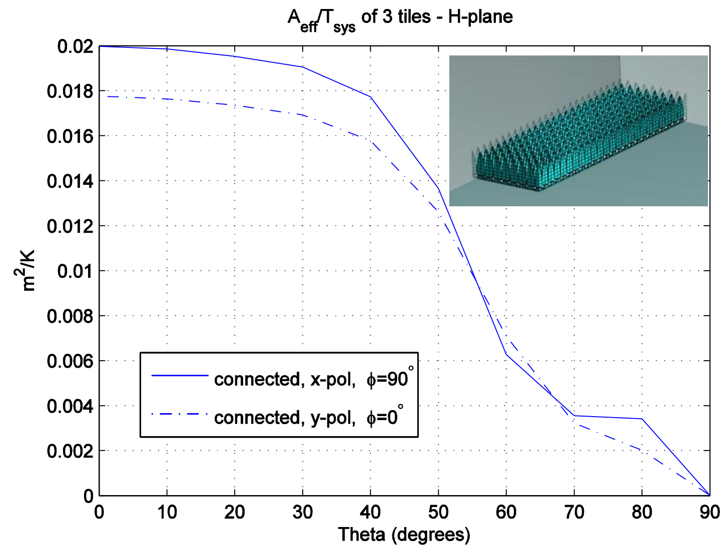
- Polarization,
- Sensitivity.

1 to 3 Embrace-like tiles

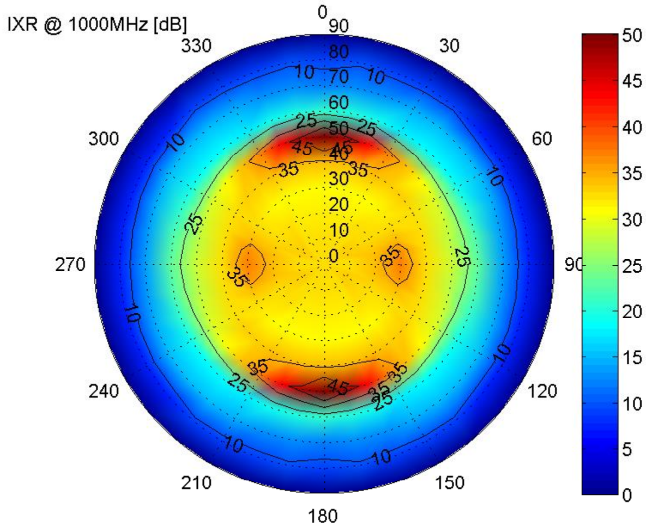


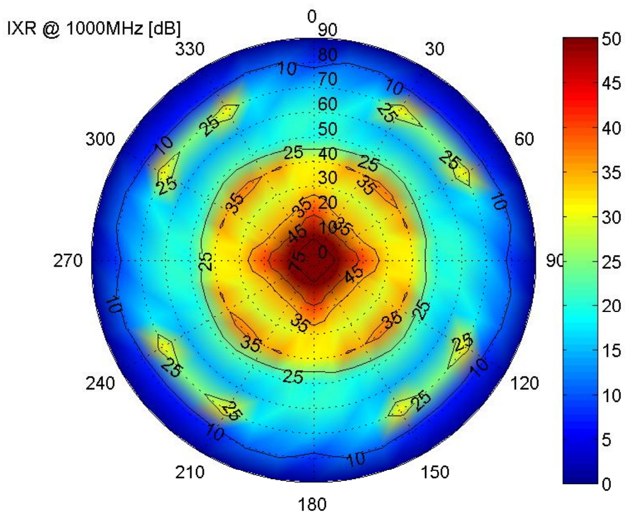




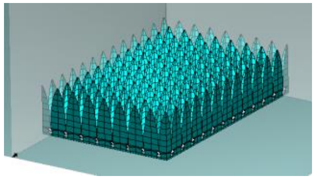


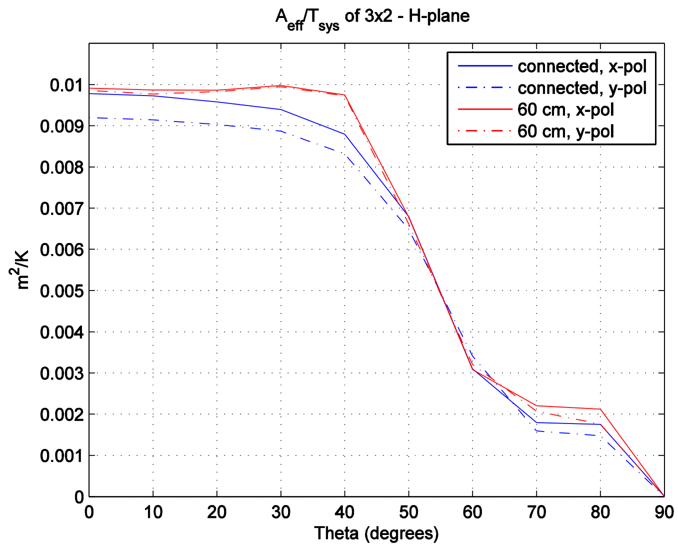
Asymmetry – 3x2



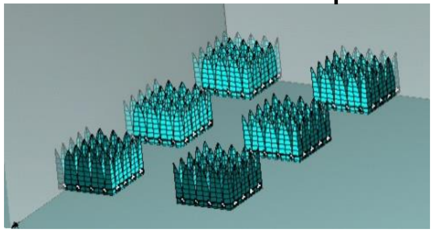


3x2 - No interspacing

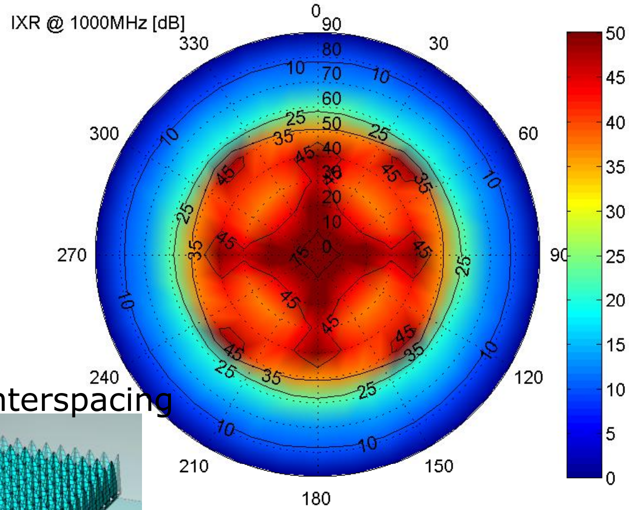




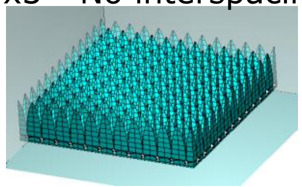
3x2 – 60cm interspacing

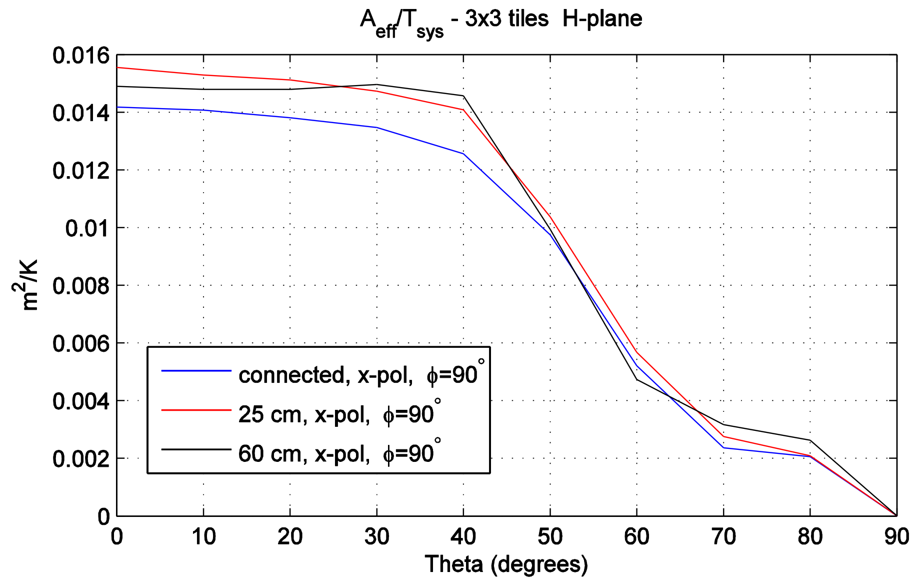


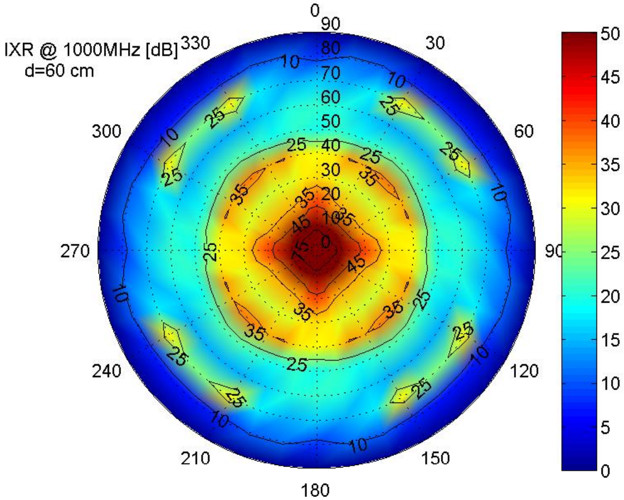
Tile separation – 3x3

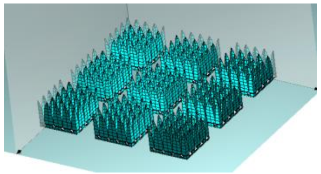


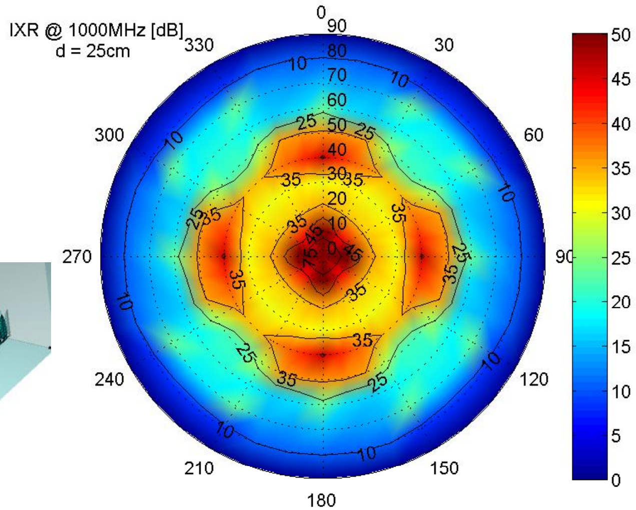
3x3 - No interspacing





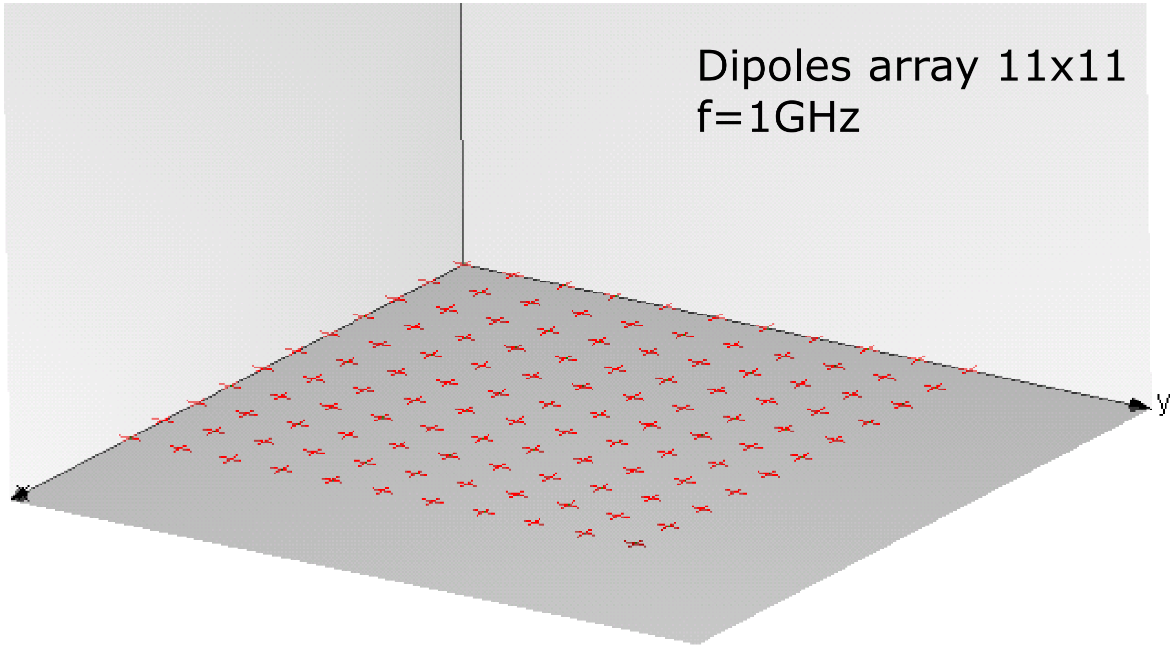




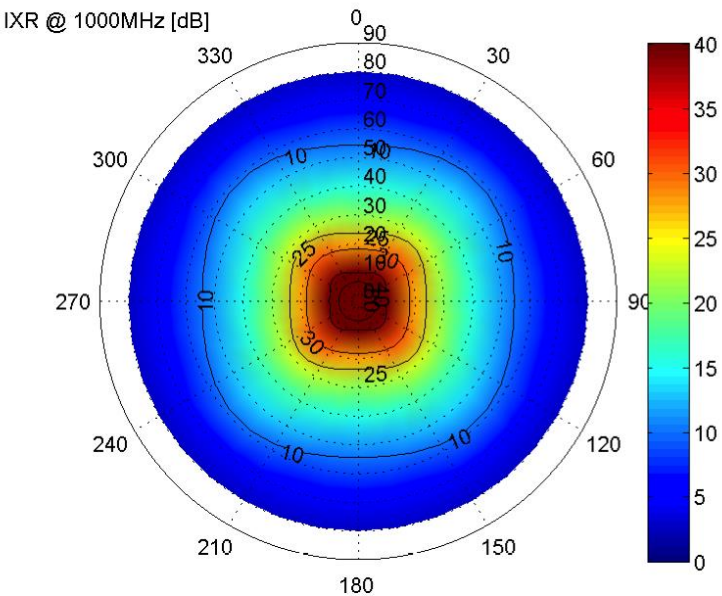


Previous study on array sparseness:
Which is the level of sparseness allowing the single element analysis?

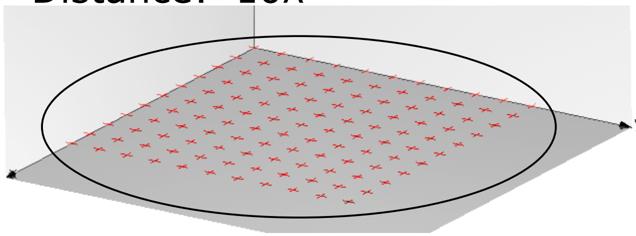
Worse case: regular array

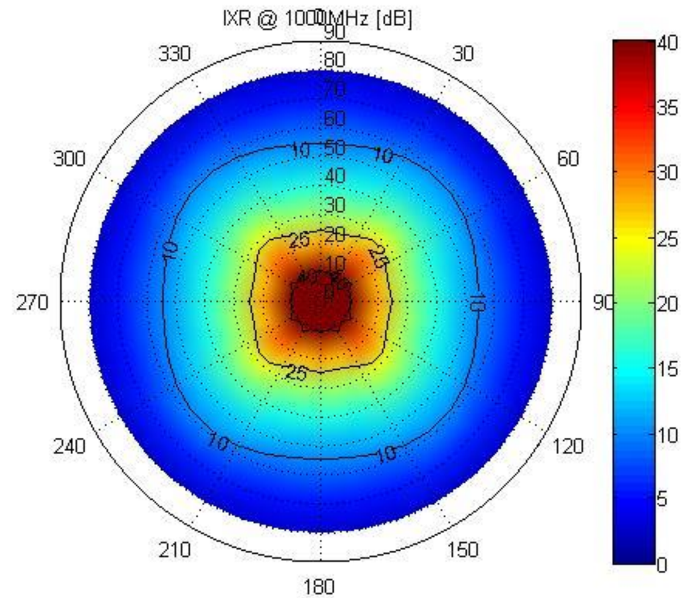


Single element

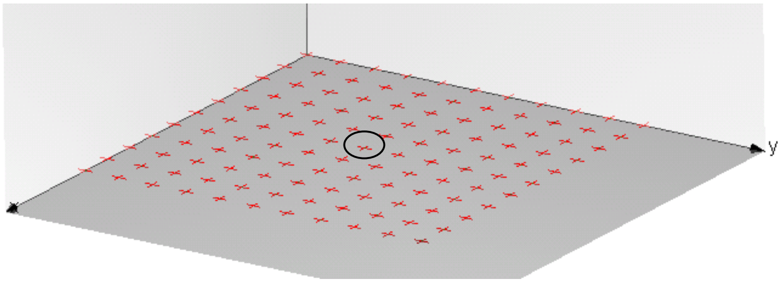


Whole array
Distance: 10λ

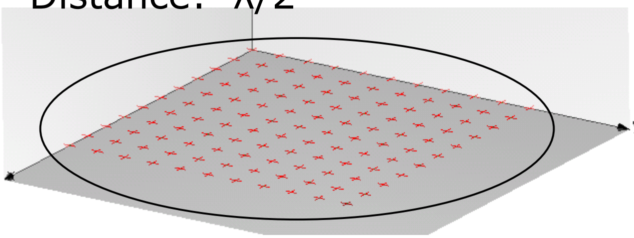


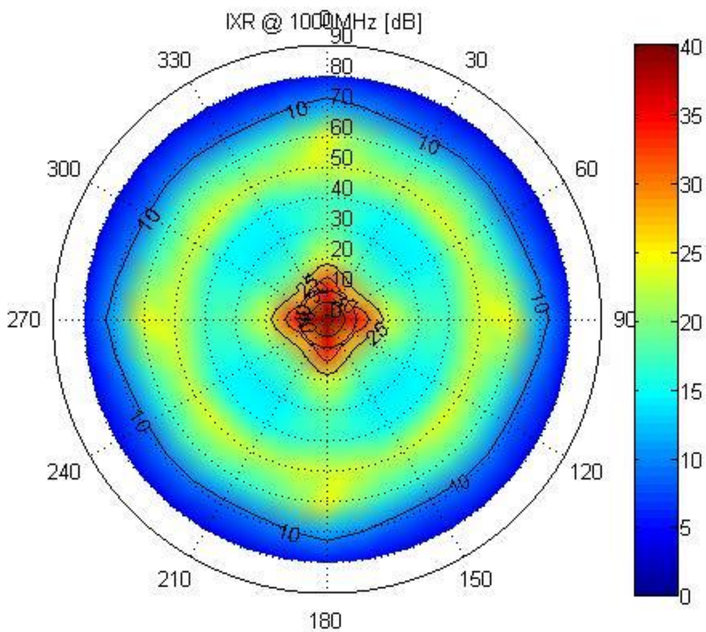


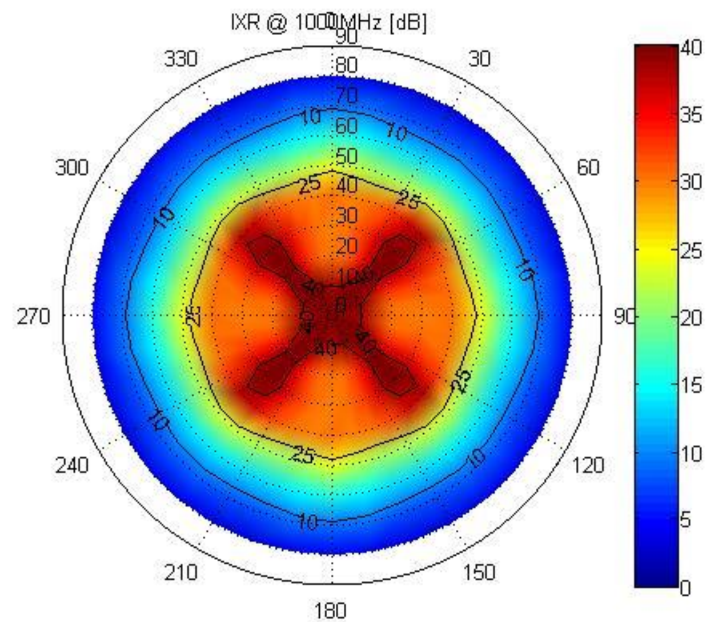
Central embedded element
Distance: λ/2



Whole array
Distance: λ/2

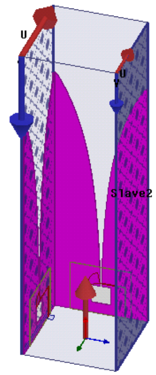


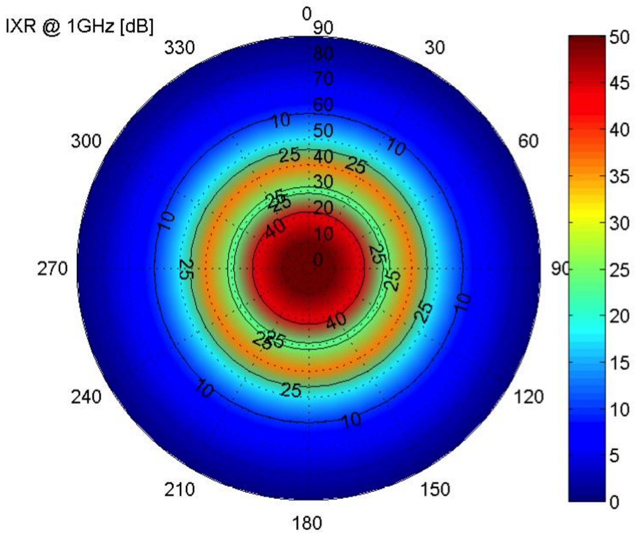




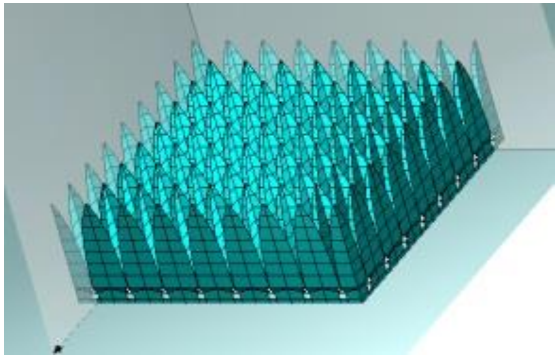
Dense Regular array

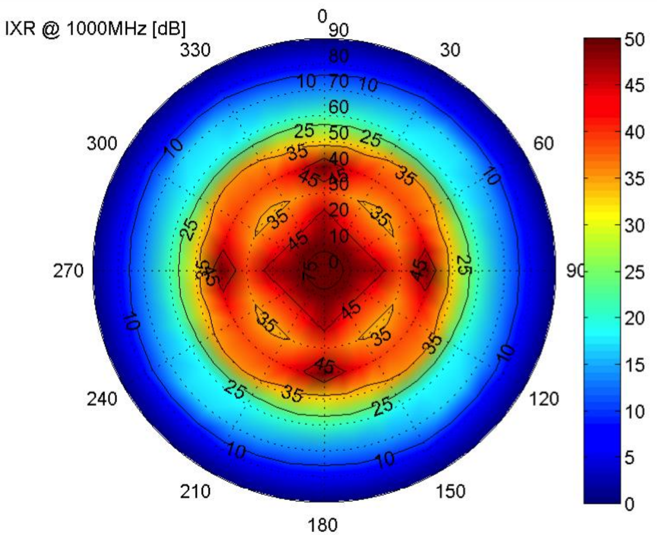
Infinite array





144 elements array





Conclusions

- Asymmetry of the tiles configuration degrades the polarization performances.
- Mutual coupling and finiteness of the array improve the polarization performances at higher scanning angles (Theta>30 deg).
- When symmetry is preserved, the improvement is present at every scanning angle, including the region close to zenith.
- Tiles separation doesn’t degrade the polarization performances and sensitivity of the finite array (up to 2 lambda).

Future work

- Study: Tile sizing, Tile separation sizing, Station configuration.
- Further studies are required to evaluate the reliability of the infinite array approximation as function of the array size.

Thank you.