AN INVESTIGATION OF ADAPTIVE ACQUISITION TECHNIQUES FOR PLANAR NEAR-FIELD ANTENNA MEASUREMENTS

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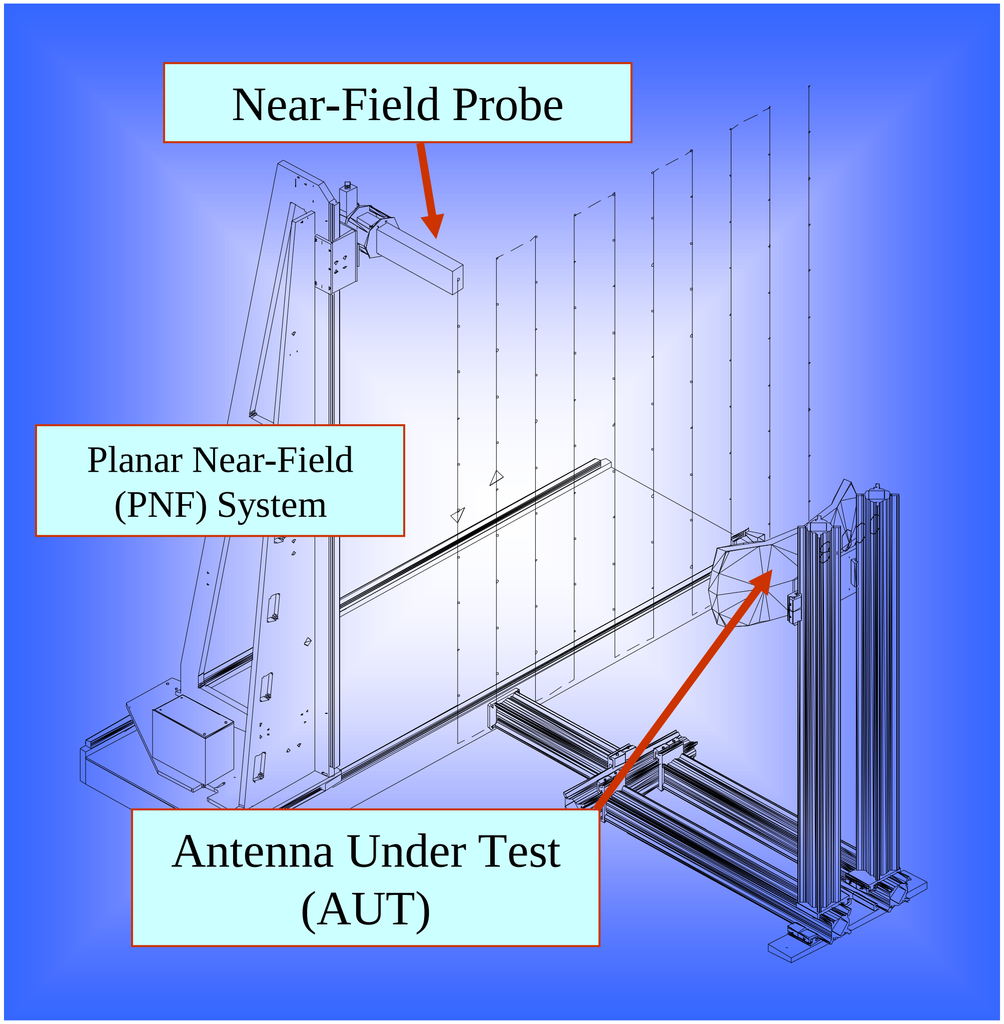
Outline of Presentation

- Purpose of the Work
- Quick Review of What Others Have Done
- Description of an Algorithm to Achieve this Purpose
- Two Examples
- Conclusions

Purpose of the Work



Goal

Reduce Near-Field Data Acquisition Time

↓

Using an Existing Conventional PNF Facility & Operation

↓

Data Acquisition Time
(Physical Movement of the Probe)
Dominates Testing Time

↓

Work Represents Our Moving in the Direction of Building Feedback/Adaptivity into Near-Field Measurements

Purpose of the Work

Scan Size Estimation - Linear Axis

A.C.Newell, "Error analysis techniques for planar near-field measurements", IEEE Transactions on Antennas & Propagation, Vol.36, No.6, p.754-768, June 1988.

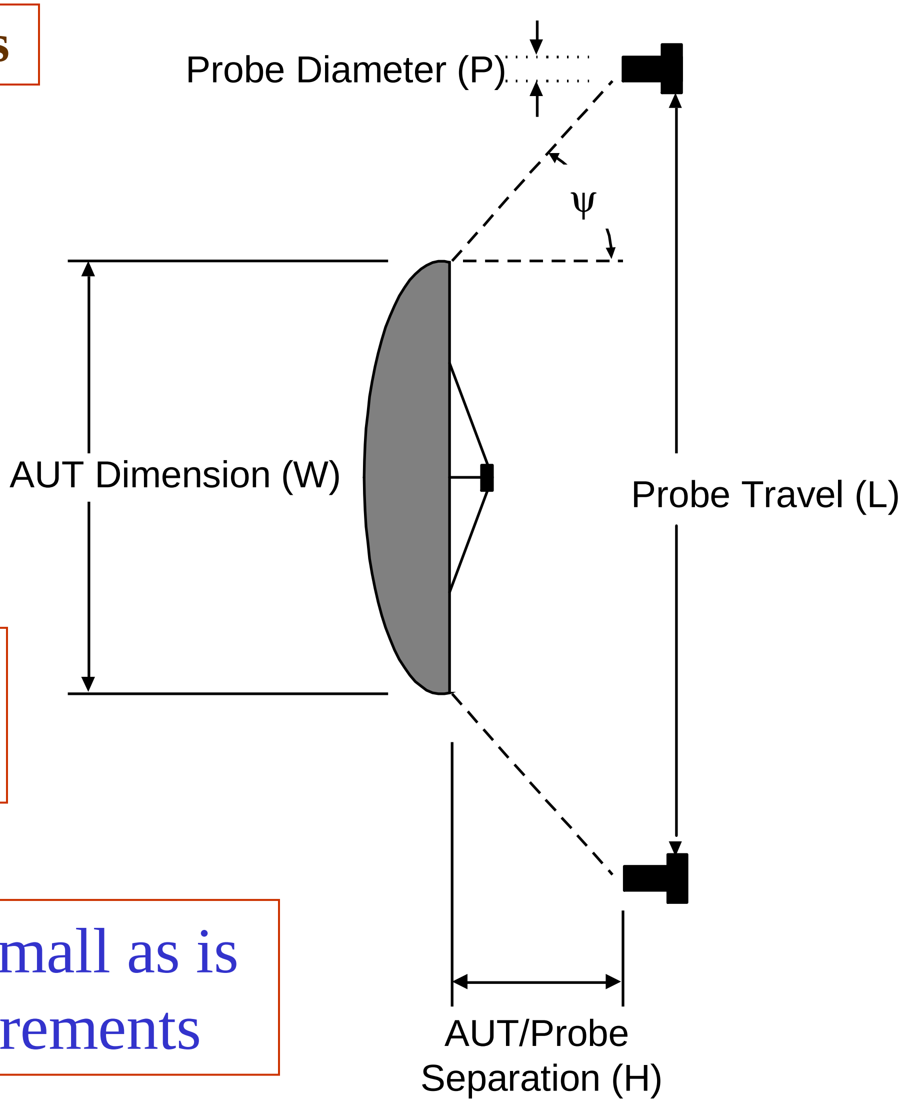
$$L \geq W + P + 2H \tan(\psi)$$

↑

In Order to Avoid Excessive **Truncation Error**

↑

We Would Like **L** to be as Small as is Necessary for Stated Requirements



Quick Review of What Others Have Done

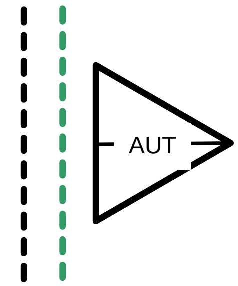
Given An Existing Planar Near-Field Test Facility of a Certain Maximum Scan Area – Two Questions Have Been Asked By Various Authors :

- ❑ How can we test an antenna that is just too large for the facility? (If we wish to determine radiation patterns out to some prescribed angle)

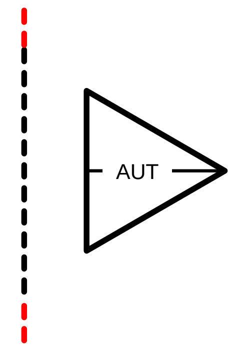
- ❑ How can we reduce the data acquisition time when using the facility?

Quick Review of What Others Have Done

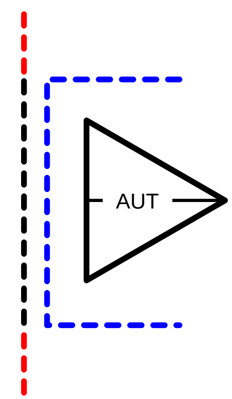
P.Petre & T.K.Sarkar, *IEEE Transactions on Antennas & Propagation*, Vol.40, No.11, pp.1348-1356, **Nov.1992**.
P.Petre & T.K.Sarkar, Progress in Electromagnetics Research, *PIER Vol.12*, pp.37-56, **1996**.



O.M.Bucci, G.D'Elia & M.D.Migliore, *Radio Science*, Vol.35, No.1, pp.3-18, **Jan.-Feb. 2000**.
J-C.Bolomey, O.M.Bucci, et al., *IEEE Transactions on Antennas & Propagation*, Vol.52, No.2, pp.593-602, **Feb.2004**.



O.M.Bucci & M.D.Migliore, *Electronic Letters*, Vol.39, No.10, p.765-766, **May 2003**.
O.M.Bucci & M.D.Migliore, *IEEE Transactions on Antennas & Propagation*, Vol.54, No.10, pp.2940-2952, **Oct.2006**.



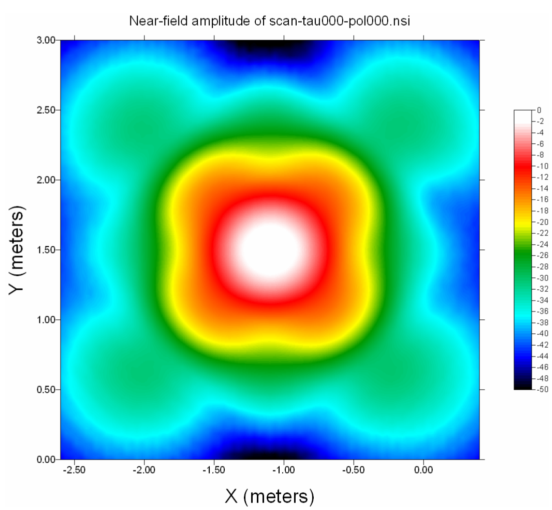
Quick Review of What Others Have Done

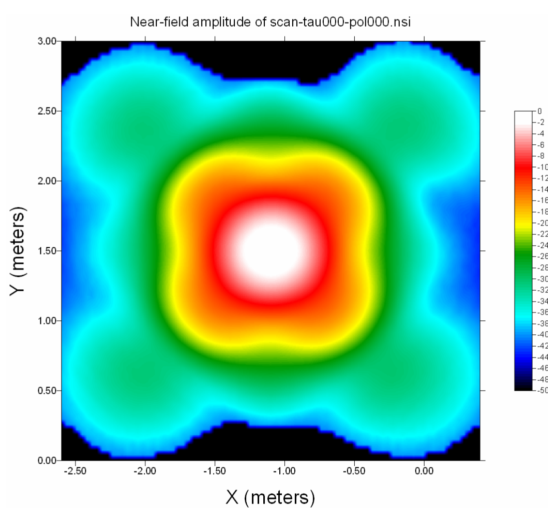
D.J.Janse van Rensburg, *IEEE Antennas and Propagation Magazine*, Vol.46, No.6, p.179-184, **Dec. 2004**.

- Acquire Near-Field Data on Scan Plane Defined by Expected Constant Field Intensity Contours

- Requires Initial Large Complete Data Set to Determine Expected Field Intensity Contours

- Allows Test-Time Reduction in Subsequent Data Acquisitions of 10% - 20%





Only Those Low Values That Will Lead to Actual Data Acquisition Time Reduction Are Excluded (In This Case For Y-Axis Scanning)

Processing Time vs Data Acquisition Times

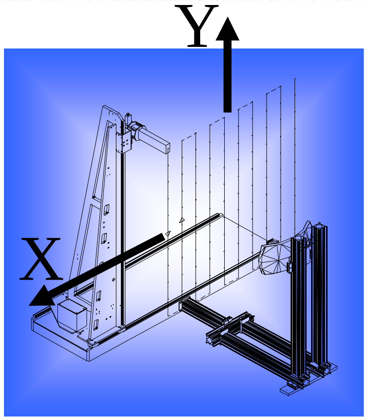
- Data Acquisition Times Measured in Minutes or Hours (Physical Movement of the Probe)

- Data Processing Times Measured in Seconds

We Have Begun Trying The Following Approach:

- Identify Performance Indices Required
- Identify Accuracy Required
- Reduce Near-Field Data Acquisition Time by Requiring the Minimum Near-Field Data Necessary for Above Requirements
- Achieve this by Using *Adaptive Algorithm* to Terminate Near-Field Data Acquisition

Description of the Algorithm



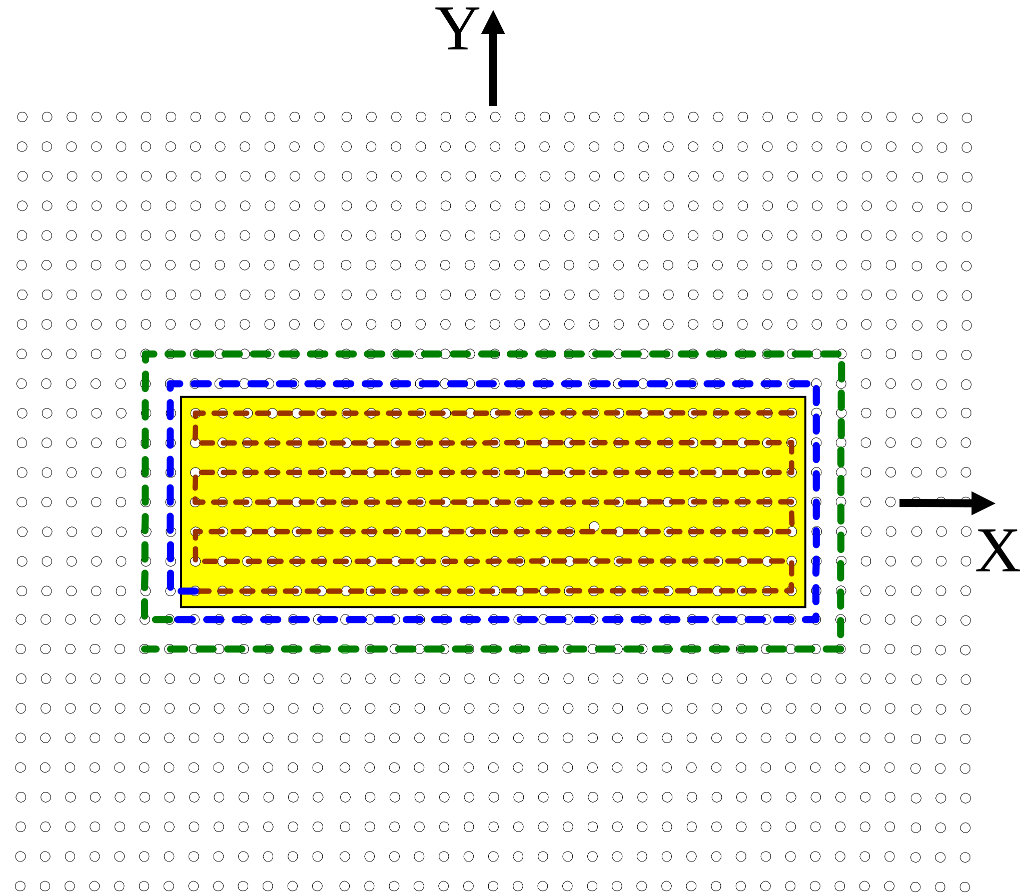
- AUT Physical Aperture

- Possible Sampling Points (**o**)

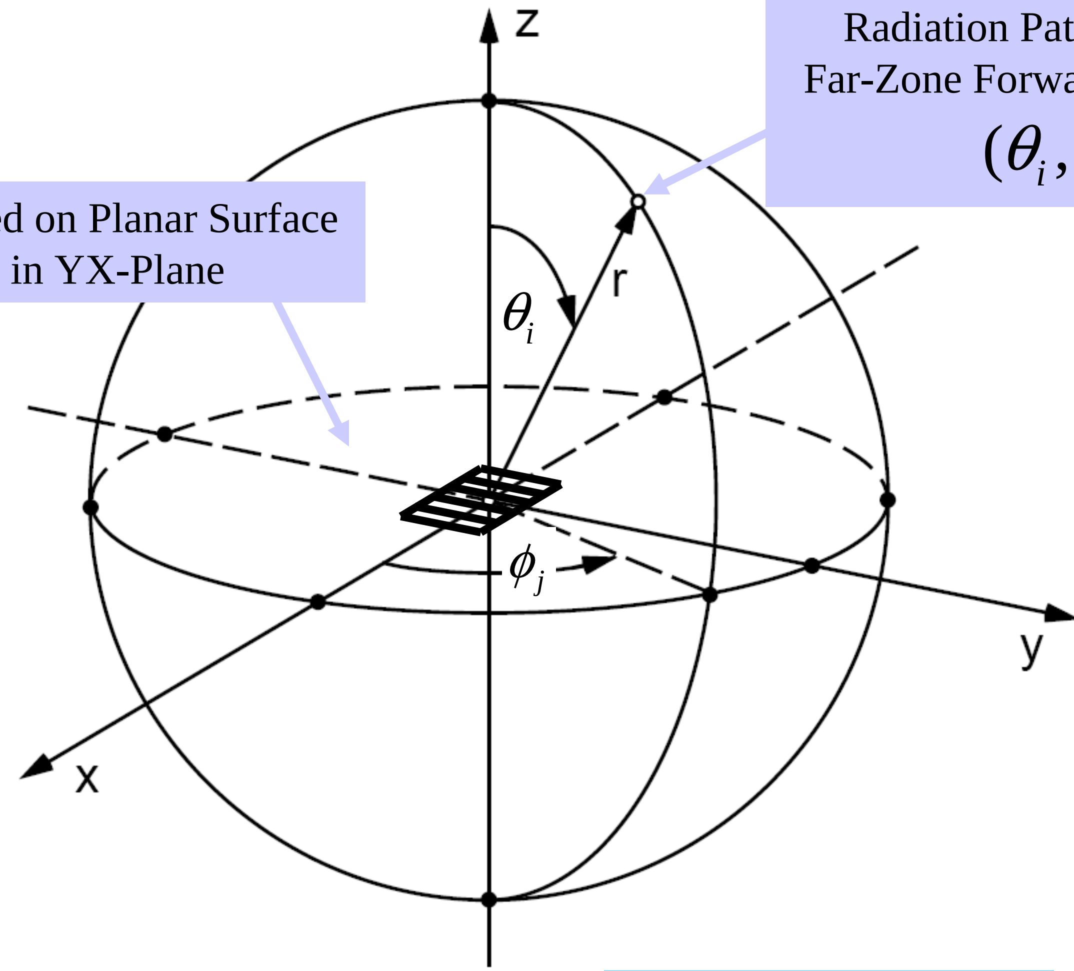
- **Probe Paths After :**

  $(n-1)$ th Iteration (- - -) + (- - -)

  n th Iteration (- - -) + (- - -) + (- - -)



Description of the Algorithm



Data Sampled on Planar Surface Lying in YX-Plane

Radiation Pattern Point on Far-Zone Forward Hemisphere (θ_i, ϕ_j)

Compute These at End of n-th Iteration

$$E^n_{co}(\theta_i, \phi_j)$$

$$E^n_{cr}(\theta_i, \phi_j)$$

$$i = 0, 1, 2, \ldots\ldots, I_{max}$$

$$j = 0, 1, 2, \ldots\ldots, J_{max}$$

I_{max} J_{max} ← Number of Far-Zone Sampling Points for Use in Error Function

Description of the Algorithm

Quantities To Be Selected By "The User" Are Underlined Using ═

(θ_i, ϕ_j) $\quad i = 0,1,2,\ldots\ldots, \underline{\underline{I_{\max}}}$ $\quad j = 0,1,2,\ldots\ldots, \underline{\underline{J_{\max}}}$

$E_{co}^{n}(\theta_i, \phi_j)$

P_{co} Sets Level (dB) Below Which Radiation Pattern is Considered Insignificant

$$\left|\tilde{E}_{co}^{n}(\theta_i, \phi_j)\right| = \left|E_{co}^{n}(\theta_i, \phi_j)\right| / \underline{\underline{\left|E_{Norm}(\theta_o, \phi_o)\right|}}$$

$$\left|\tilde{E}_{co}^{n}(\theta_i, \phi_j)\right| = \begin{cases} \left|\tilde{E}_{co}^{n}(\theta_i, \phi_j)\right| & \text{if } 20\log\left|\tilde{E}_{co}^{n}(\theta_i, \phi_j)\right| \ge \underline{\underline{P_{co}}} \\ 10^{P_{co}/20} & \text{Otherwise} \end{cases}$$

$$f_{co}^{n}(\theta_i, \phi_j) = \left|\tilde{E}_{co}^{n}(\theta_i, \phi_j)\right| - \left|\tilde{E}_{co}^{n-1}(\theta_i, \phi_j)\right|$$

"Error" (Difference) Terms

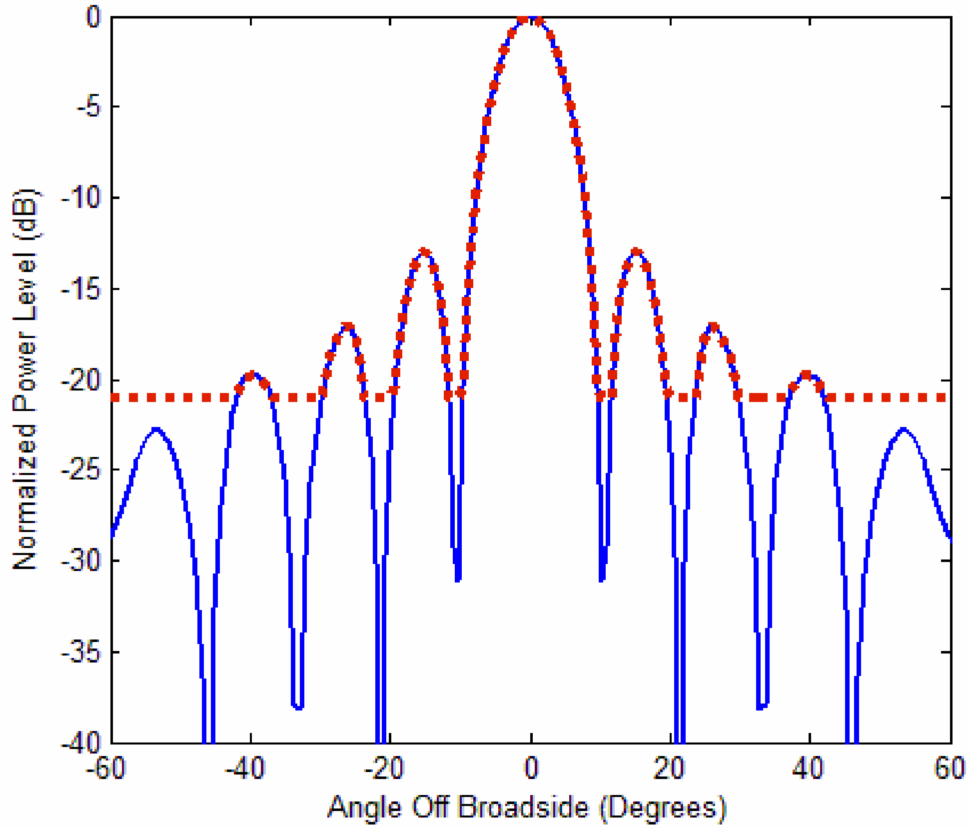
$E_{cr}^{n}(\theta_i, \phi_j)$

Similarly for Cross-Polarisation Terms

$f_{cr}^{n}(\theta_i, \phi_j)$

Index *n* is Iteration Number

Description of the Algorithm



Effect of P_{co}

P_{co} P_{cr}

Controls Dynamic Range of Radiation Patterns Considered to be Significant

Description of the Algorithm

Quantities To Be Selected By "The User" Are Underlined Using ══

(θ_i, ϕ_j) $\quad i = 0,1,2,\ldots\ldots, \underline{I_{\max}}$ $\quad j = 0,1,2,\ldots\ldots, \underline{J_{\max}}$

P_{co} Sets Level Below Which Radiation Pattern is Considered Insignificant

$E_{co}^{n}(\theta_i, \phi_j)$

$$\left|\tilde{E}_{co}^{n}(\theta_i, \phi_j)\right| = \left|E_{co}^{n}(\theta_i, \phi_j)\right| / \underline{\left|E_{Norm}(\theta_o, \phi_o)\right|}$$

$$\left|\tilde{E}_{co}^{n}(\theta_i, \phi_j)\right| = \begin{cases} \left|\tilde{E}_{co}^{n}(\theta_i, \phi_j)\right| & \text{if } 20\log\left|\tilde{E}_{co}^{n}(\theta_i, \phi_j)\right| \geq \underline{P_{co}} \\ 10^{P_{co}/20} & \text{Otherwise} \end{cases}$$

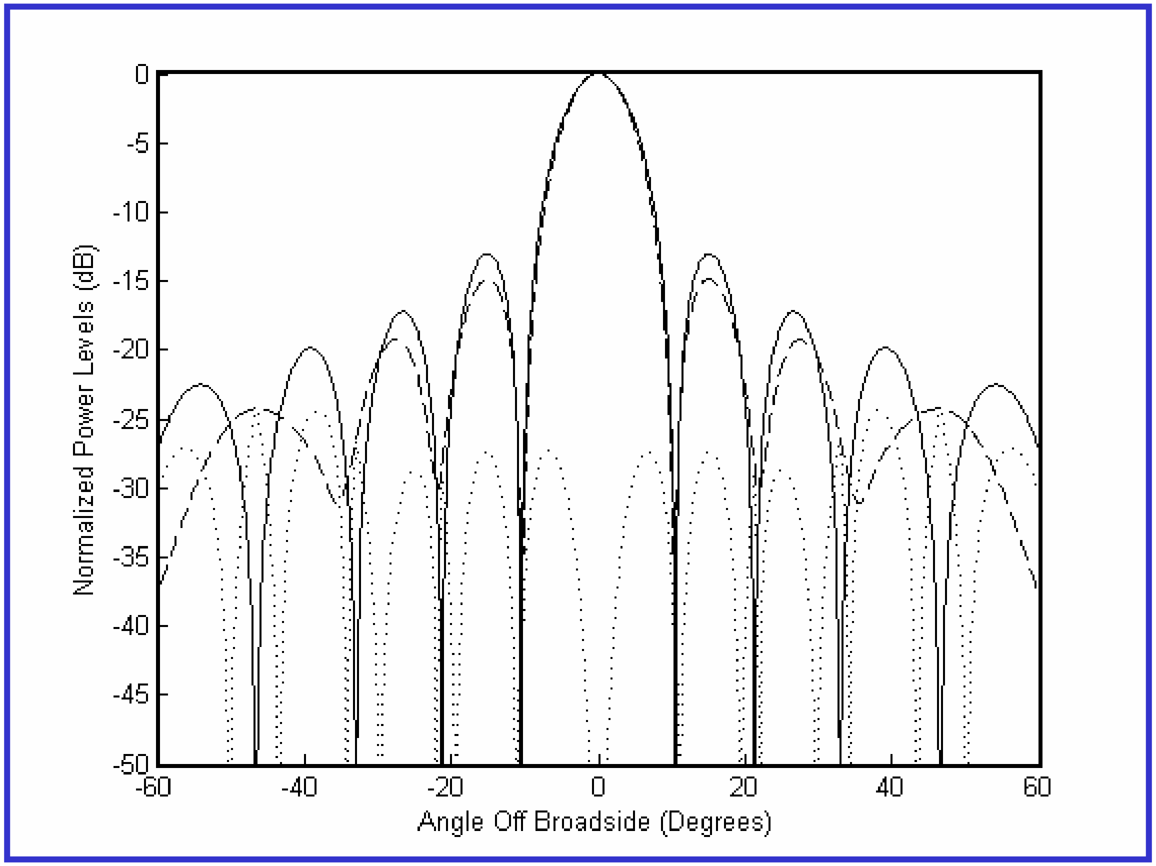
$$f_{co}^{n}(\theta_i, \phi_j) = \left|\tilde{E}_{co}^{n}(\theta_i, \phi_j)\right| - \left|\tilde{E}_{co}^{n-1}(\theta_i, \phi_j)\right|$$

$E_{cr}^{n}(\theta_i, \phi_j)$

Similarly for Cross-Polarisation Terms

$f_{cr}^{n}(\theta_i, \phi_j)$

Experimental Validation



11 x 11 Element Array (Theoretical)

Exact Radiation Pattern (————)

Pattern Computed Using PNF Technique with the Sampling Plane Deliberately Undersized (— — — — —)

Error Terms (……………...) ⟵ $20\log_{10}\left\{\left|\tilde{E}_{co}^{exact}(\theta_i,\phi_j)\right|-\left|\tilde{E}_{co}^{inexact}(\theta_i,\phi_j)\right|\right\}$

Description of the Algorithm

Decision Function = Average of the Error Terms for Each Angular Direction

$$F_n = 20\log\left\{\frac{\sum_{i=1}^{I_{\max}}\sum_{j=1}^{J_{\max}}\left\{w_{co}(\theta_i,\phi_j)\, f_{co}^{\,n}(\theta_i,\phi_j)\right\}}{I_{\max}J_{\max}}\right\} + 20\log\left\{\frac{\sum_{i=1}^{I_{\max}}\sum_{j=1}^{J_{\max}}\left\{w_{cr}(\theta_i,\phi_j)\, f_{cr}^{\,n}(\theta_i,\phi_j)\right\}}{I_{\max}J_{\max}}\right\} + F_{scale}$$

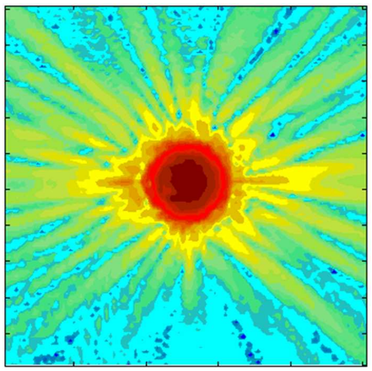
$$\left.\begin{matrix} w_{co}(\theta_i,\phi_j) \\ w_{cr}(\theta_i,\phi_j) \end{matrix}\right\}$$

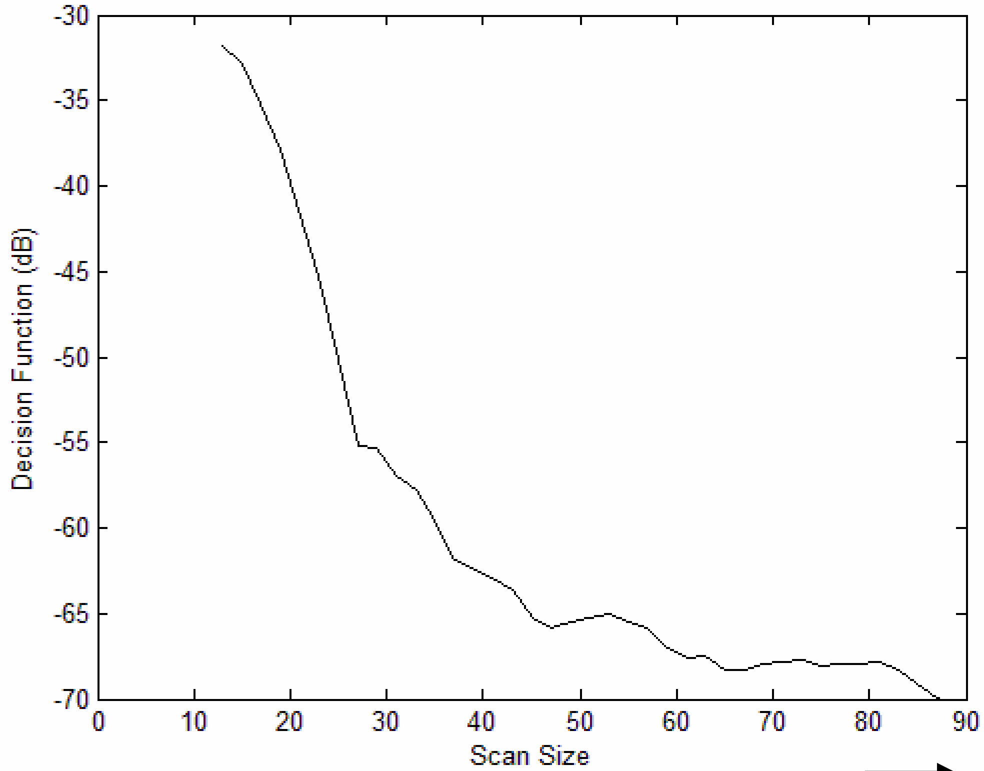
Weights Used to Emphasise the Relative Importance of One Angular Portion of the Radiation Pattern Over Another

The number of iterations is continued (and hence the sampling plane size increased) until $F_n \le F_{\text{Threshold}}$

Example#1

Planar Array





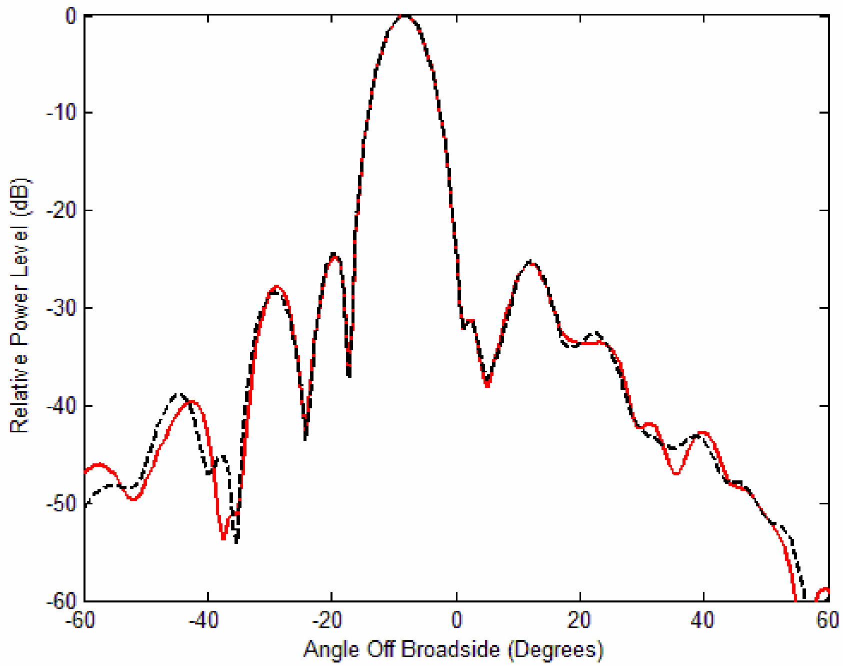
P_{co} = - 60dB
w_{co} = 1.0
w_{cr} = 0.0

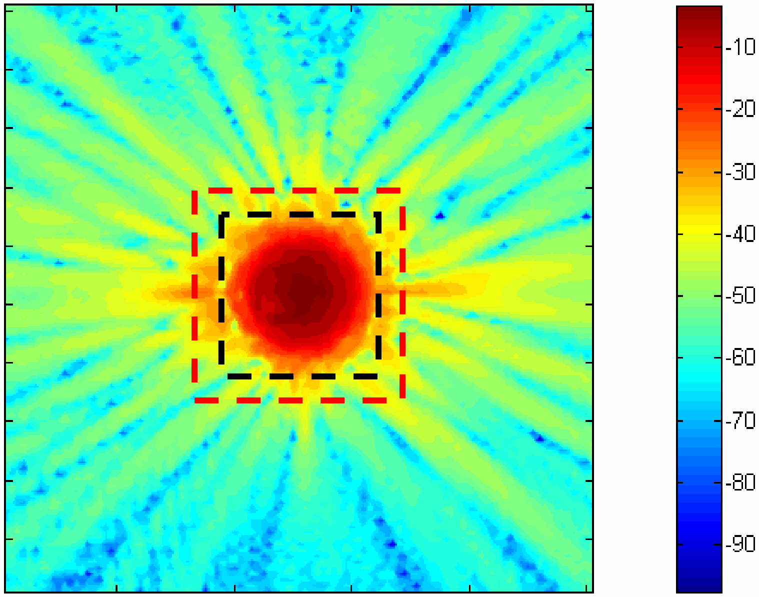
Increasing Iteration Number

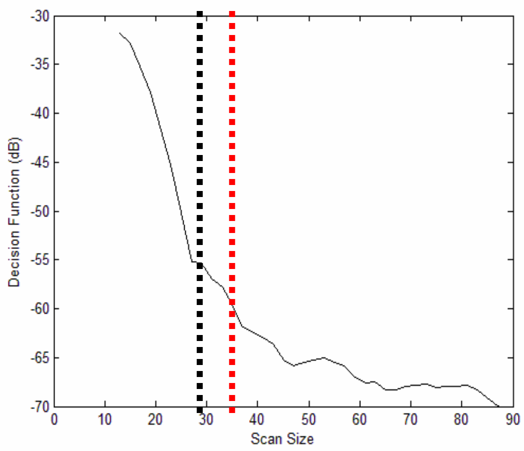
$F_{\text{Threshold}}$

Threshold Value for the Decision Function (“Stopping Criterion”)

Example#1



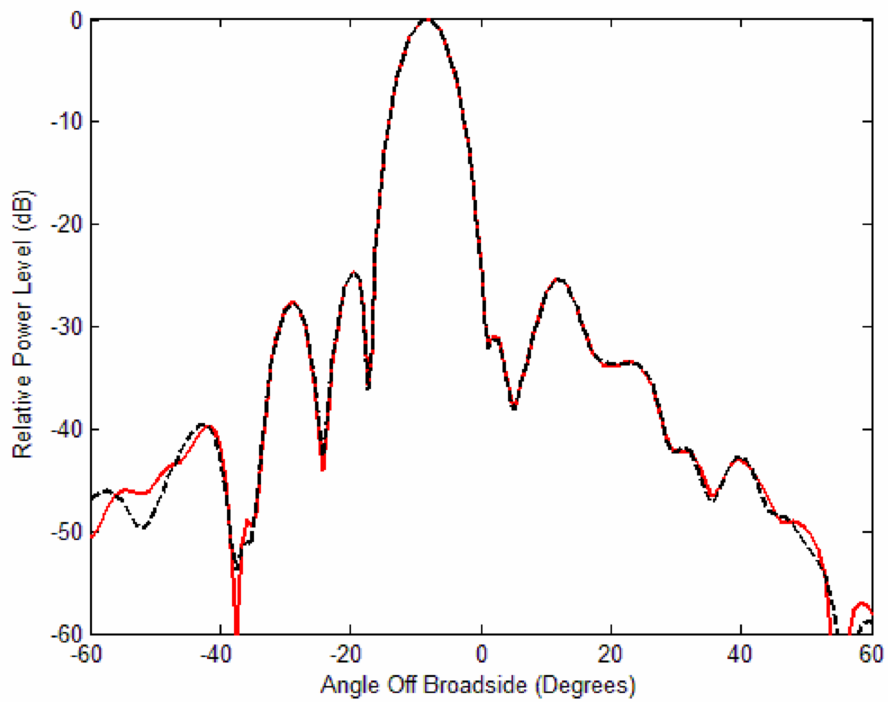


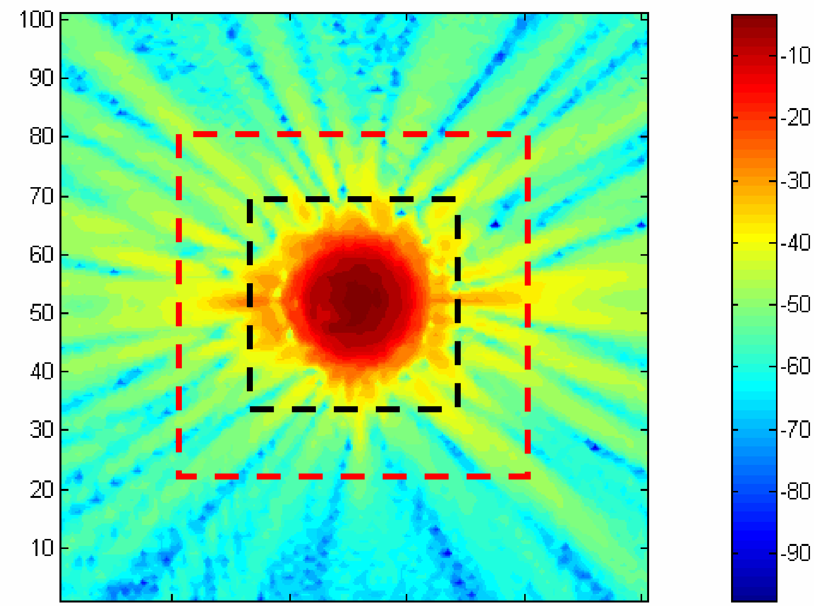


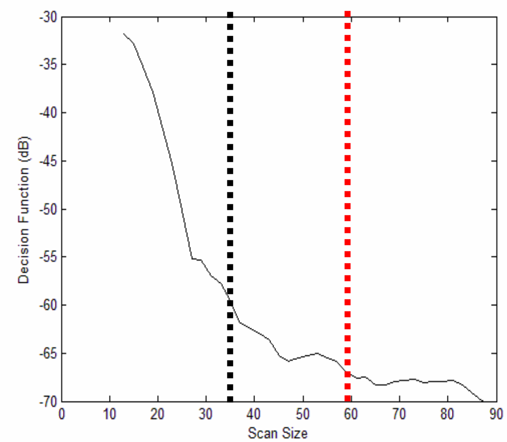
F_n = -55.36 dB

F_n = -59.51 dB

Example#1





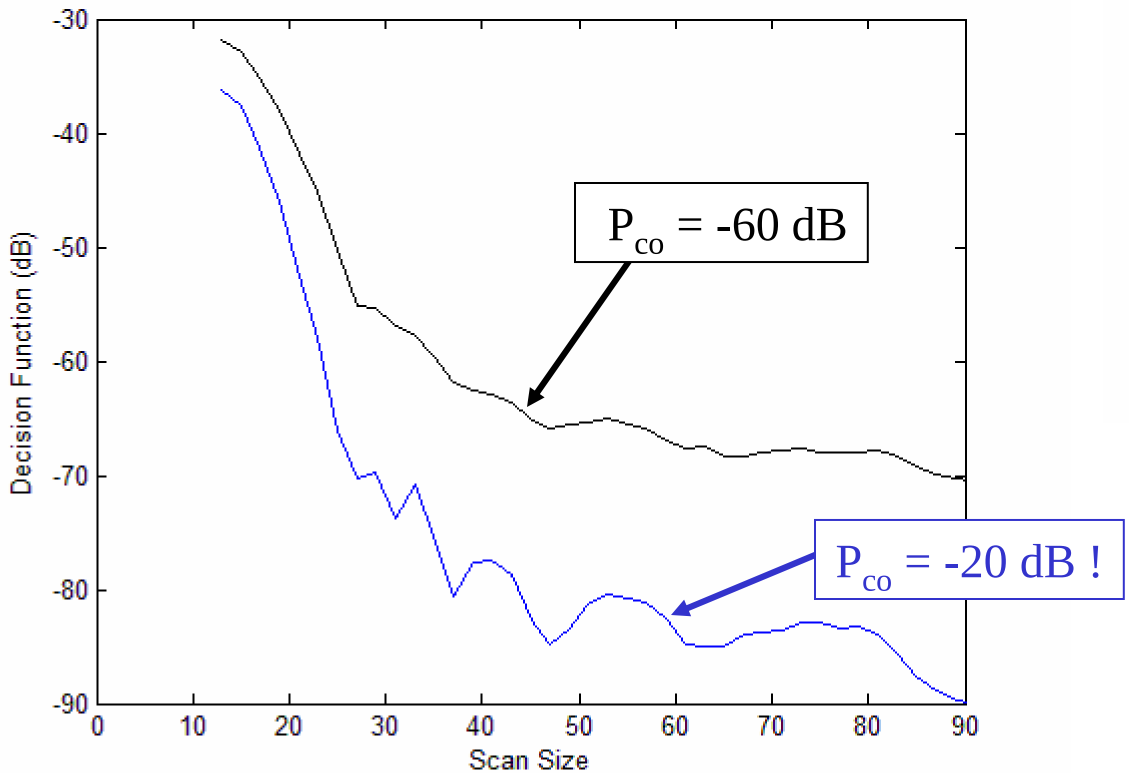


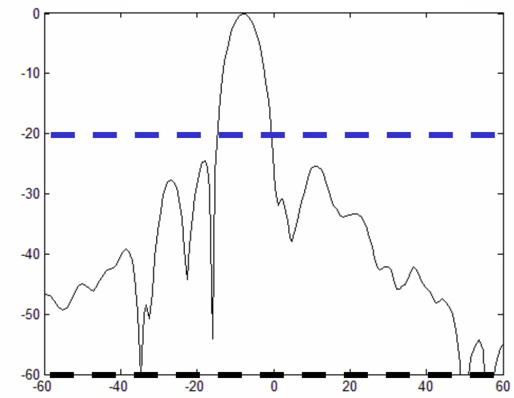
- - - - F_n = -59.5 dB

——— F_n = -67.0 dB

SCAN SIZE	ACQUISITION “TIME”
90	T_o
59	0.43 T_o
35	0.15 T_o

Example#1





Increasing Iteration Number

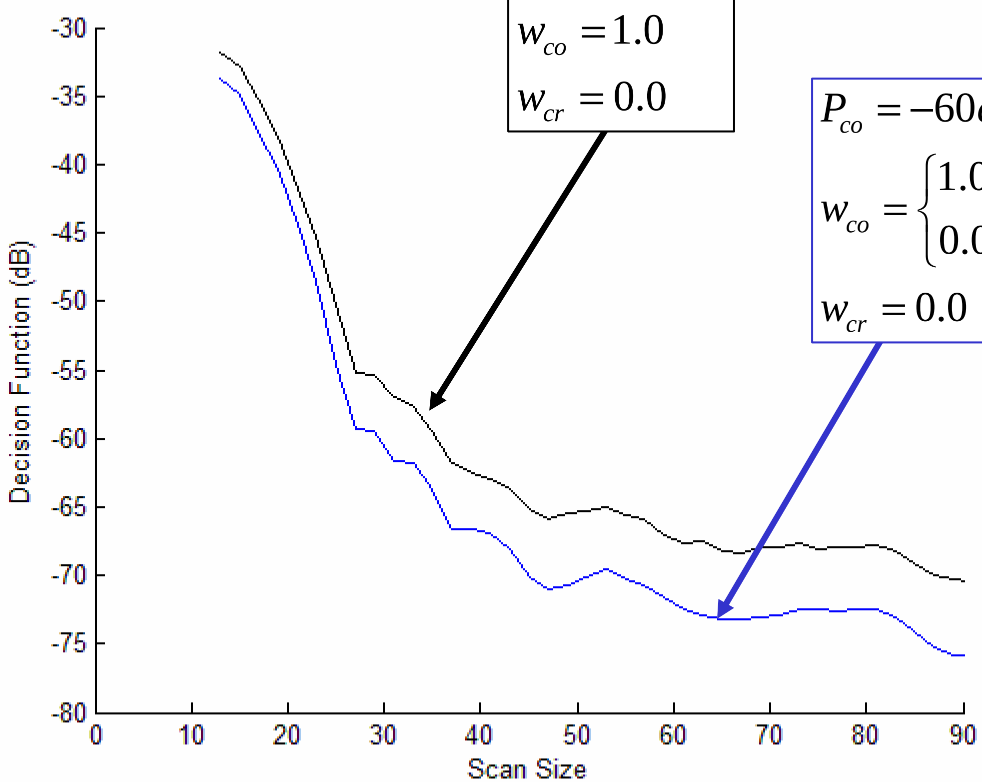
Example#1

$P_{co} = -60dB$
$w_{co} = 1.0$
$w_{cr} = 0.0$

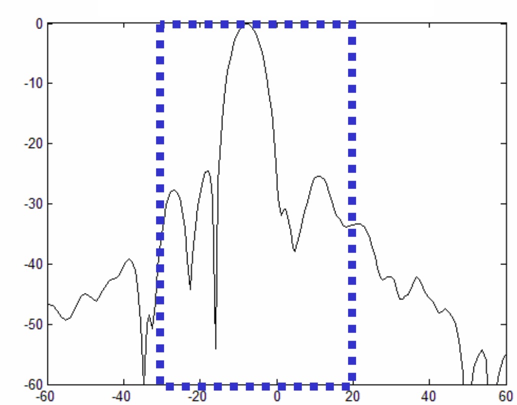
$P_{co} = -60dB$

$$w_{co} = \begin{cases} 1.0 & \text{Restricted Angular Region} \\ 0.0 & \text{Otherwise} \end{cases}$$

$w_{cr} = 0.0$



Increasing Iteration Number

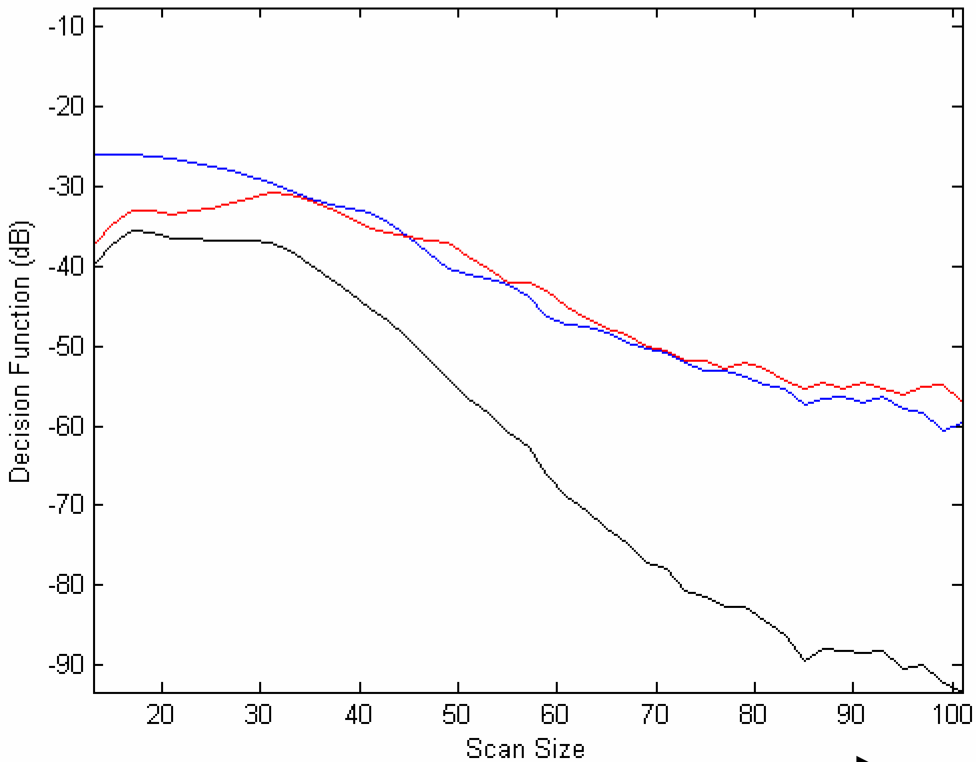


Example#2

Co-Polarization Portion of Decision Function

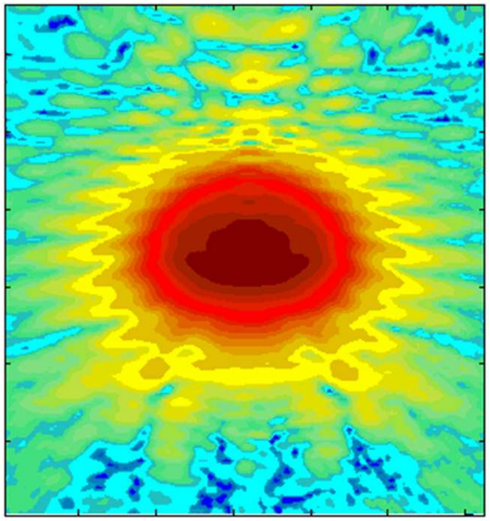
Cross-Polarization Portion of Decision Function

Overall Decision Function



Increasing Iteration Number

Offset Reflector



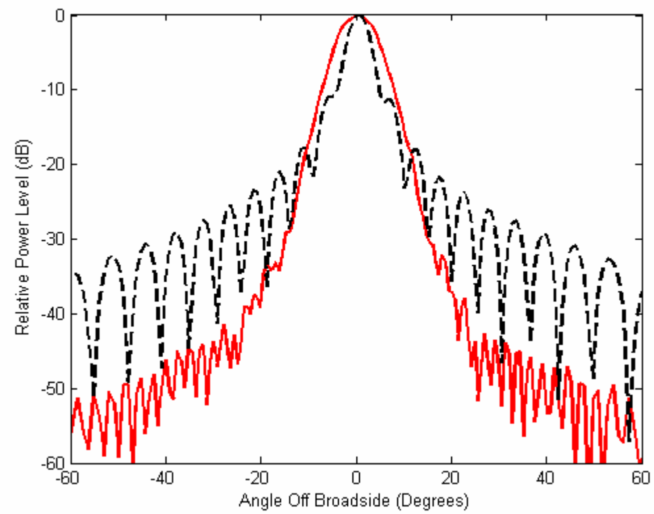
$P_{co} = P_{cr} = -60dB$

$w_{co} = 1.0$

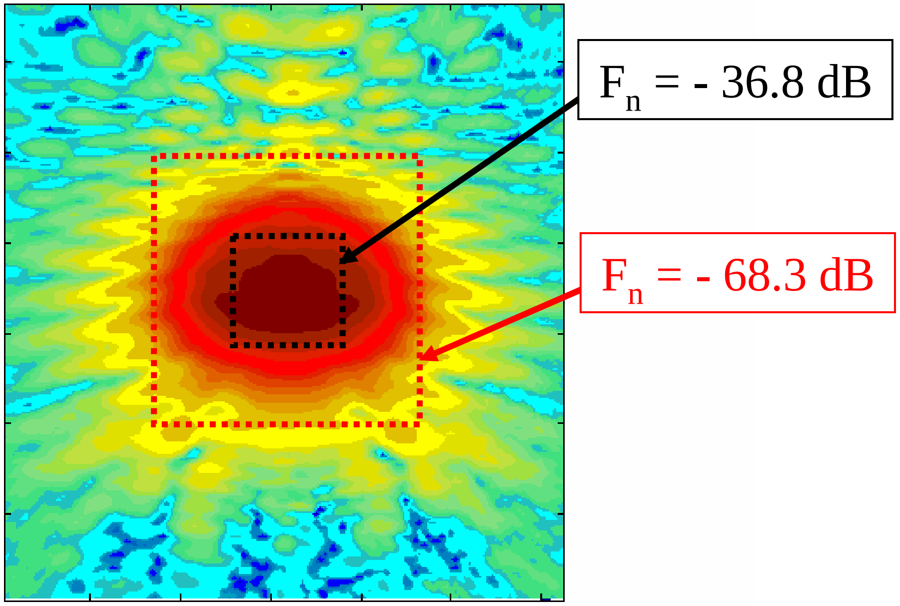
$w_{cr} = 1.0$

$F_{scale} = 23.32\ dB$

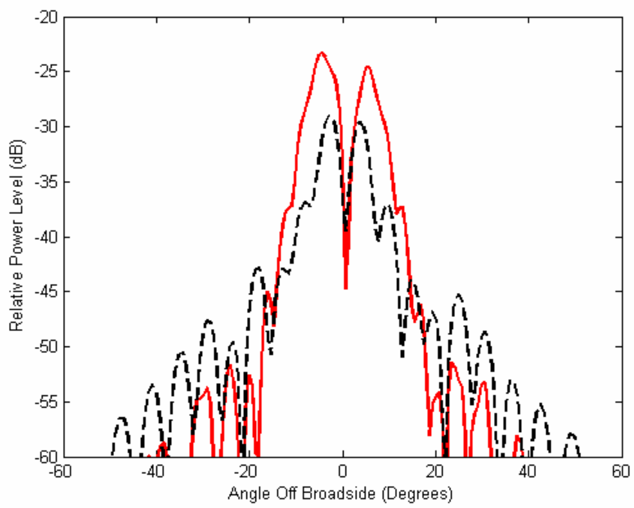
Example#2



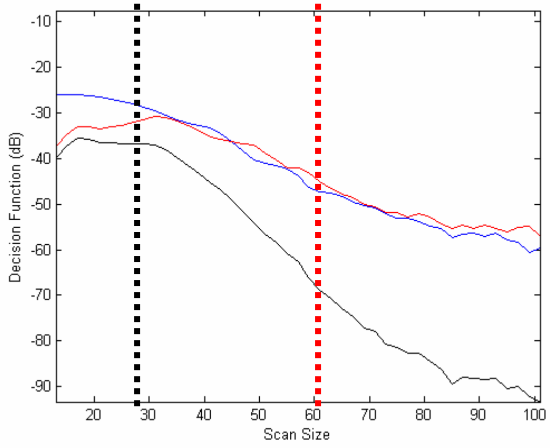
Relative Power Level (dB)
Angle Off Broadside (Degrees)



F_n = - 36.8 dB
F_n = - 68.3 dB

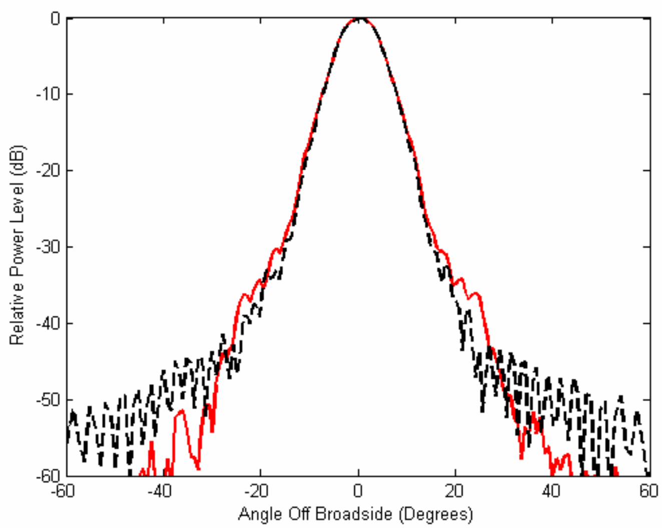


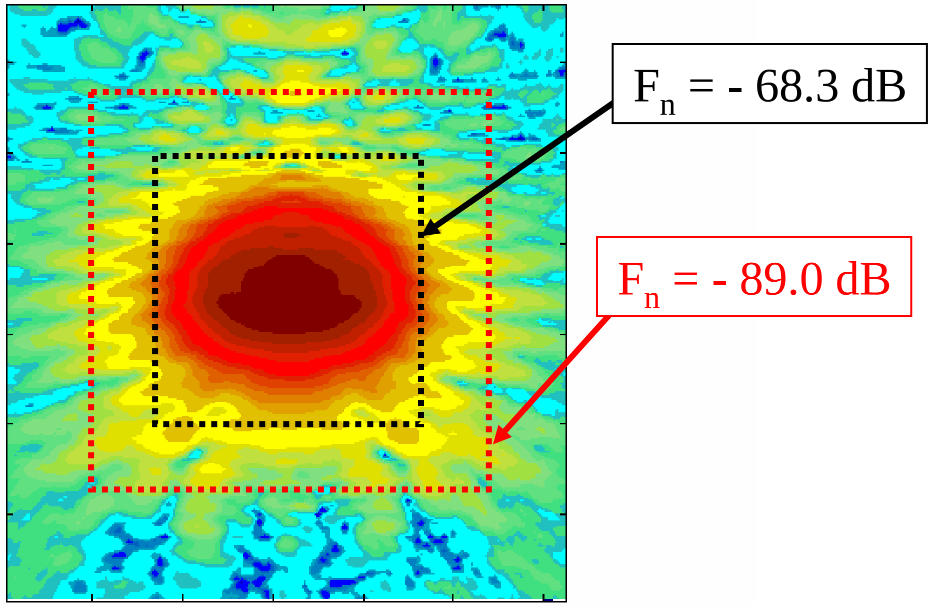
Relative Power Level (dB)
Angle Off Broadside (Degrees)

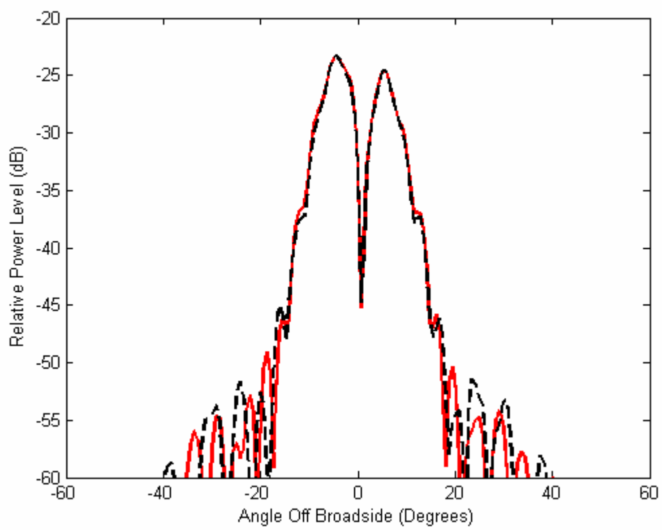


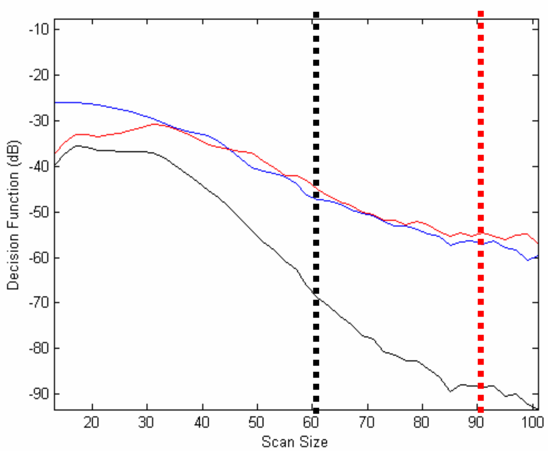
Decision Function (dB)
Scan Size

Example#2





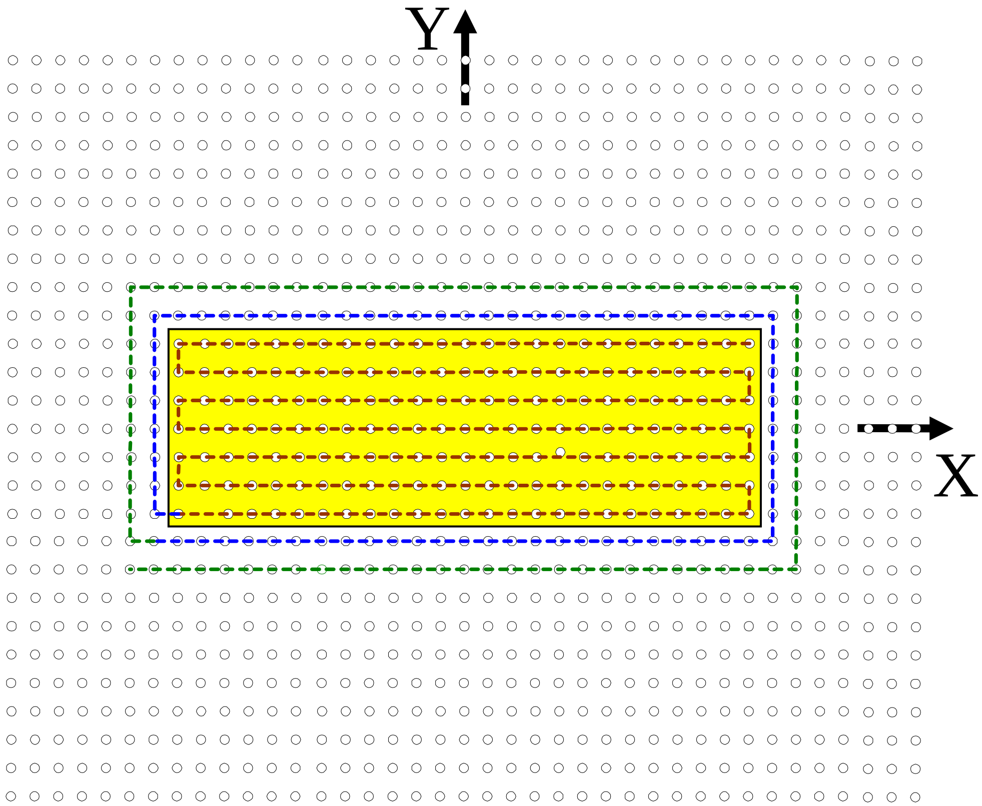




SCAN SIZE	ACQUISITION "TIME"
100	T_o
91	0.83 T_o
61	0.37 T_o

Probe Polarisation Issues

- Dual-Polarisation Probe
  - E_x and E_y Simultaneously.
- Single-Polarisation Probe
  - E_x and E_y Separately.
  - Execute Algorithm Using One Linear Polarisation (say E_y) Probe. Use Error Function to Truncate Scan Area.
  - Repeat for E_x-Polarised Probe, Including Existing E_y -Data Plus the E_x-Data in the Process of Being Acquired, in the Decision Function. Use Decision Function to Truncate Scan Area.



Alternative Decision Function Measures

- $$F_n = 20\log\left\{\underset{i,j}{Max}\left\{w_{co}(\theta_i,\phi_j)\, f_{co}^{\,n}(\theta_i,\phi_j)\right\}\right\} + 20\log\left\{\underset{i,j}{Max}\left\{w_{cr}(\theta_i,\phi_j)\, f_{cr}^{\,n}(\theta_i,\phi_j)\right\}\right\}$$

- $$F_n = 20\log\left\{D_n(\theta_0,\phi_0) - D_{n-1}(\theta_0,\phi_0)\right\}$$

Angles at which field values are needed are known *a priori*

M.Dich, IEEE Trans. Antennas Propagation, Vol.45, No.10, pp.1502-1505, Oct.1997.

C.Gennarelli, G.Riccio & C.Savarese, Journal of Electromagnetic Waves and Applications, Vol.16, No.9, pp.861-870, 2002.

- J.McCormick, S.F.Gregson & C.G.Parini, "Quantitative measures between antenna patterns" *IEE Proceedings*, Dec.2005

- Combinations of the Above

Conclusions

- Work represents a first step in our moving towards building feedback / adaptivity into near-field measurements.

- The far-zone field computation time is negligible compared to the data acquisition time.

- Can perform such computations repeatedly while data is being acquired.

- Use these computations as part of an adaptive algorithm intent on reducing the amount of data that has to be acquired.

- Uncomplicated way of potentially reducing overall antenna testing time.

- Have illustrated this using real data in two antenna examples for PNF system.

- Future work will consolidate details of study & apply to cylindrical system.