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


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

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


Quick Review of What Others Have Done


- 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)
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: \((\rightarrow \rightarrow) + (\xrightarrow{\rightarrow})\)
  - \(n\)th Iteration: \((\rightarrow \rightarrow) + (\xrightarrow{\rightarrow}) + (\xrightarrow{\rightarrow})\)
Data Sampled on Planar Surface Lying in YX-Plane

Radiation Pattern Point on Far-Zone Forward Hemisphere $(\theta_i, \phi_j)$

Number of Far-Zone Sampling Points for Use in Error Function

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

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

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

$j = 0, 1, 2, \ldots, J_{\text{max}}$
Quantities To Be Selected By “The User” Are Underlined Using

\[ E_{co}^n(\theta, \phi) = \frac{E_{co}^n(\theta, \phi)}{E_{norm}(\theta, \phi_o)} \]

\[ |\tilde{E}_{co}^n(\theta, \phi)| = \begin{cases} |\tilde{E}_{co}^n(\theta, \phi)| & \text{if } 20\log|\tilde{E}_{co}^n(\theta, \phi)| \geq P_{co} \\ 10^{P_{co}/20} & \text{Otherwise} \end{cases} \]

\[ f_{co}^n(\theta, \phi) = |\tilde{E}_{co}^n(\theta, \phi)| - |\tilde{E}_{co}^{n-1}(\theta, \phi)| \]

\[ f_{cr}^n(\theta, \phi) \]

\[ i = 0, 1, 2, \ldots, I_{max} \]
\[ j = 0, 1, 2, \ldots, J_{max} \]

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

“Error” (Difference) Terms

Index \( n \) is Iteration Number

\[ n \] is Iteration Number
Description of the Algorithm

Effect of $P_{co}$

$P_{co}$ and $P_{cr}$ Controls Dynamic Range of Radiation Patterns Considered to be Significant
Description of the Algorithm

Quantities To Be Selected By “The User” Are Underlined

\[ (\theta_i, \phi_j) \quad i = 0, 1, 2, \ldots, I_{\text{max}} \quad j = 0, 1, 2, \ldots, J_{\text{max}} \]

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

\[ \left| \tilde{E}_{co}^n (\theta_i, \phi_j) \right| = \frac{\left| E_{co}^n (\theta_i, \phi_j) \right|}{E_{\text{Norm}} (\theta_o, \phi_o)} \]

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

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

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

\[ P_{co} \text{ Sets Level Below Which Radiation Pattern is Considered Insignificant} \]

Similarly for Cross-Polarisation Terms
Exact Radiation Pattern

Pattern Computed Using PNF Technique with the Sampling Plane Deliberately Undersized

Error Terms

\[ 20 \log_{10} \left\{ |\tilde{E}_{co}^{\text{exact}}(\theta_i, \phi_j)| - |\tilde{E}_{co}^{\text{inexact}}(\theta_i, \phi_j)| \right\} \]
Description of the Algorithm

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

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

\[ w_{\text{co}}(\theta_i, \phi_j) \]
\[ w_{\text{cr}}(\theta_i, \phi_j) \]

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 \( F_n \leq F_{\text{Threshold}} \)
Example#1

Planar Array

$P_{co} = -60\text{dB}$

$w_{co} = 1.0$

$w_{cr} = 0.0$

$F_{\text{Threshold}}$

Threshold Value for the Decision Function ("Stopping Criterion")
Example#1

- $F_n = -55.36$ dB
- $F_n = -59.51$ dB
Example#1

\[ F_n = -59.5 \text{ dB} \]

\[ F_n = -67.0 \text{ dB} \]

<table>
<thead>
<tr>
<th>SCAN SIZE</th>
<th>ACQUISITION “TIME”</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>( T_0 )</td>
</tr>
<tr>
<td>59</td>
<td>0.43 ( T_0 )</td>
</tr>
<tr>
<td>35</td>
<td>0.15 ( T_0 )</td>
</tr>
</tbody>
</table>
Example #1

Increasing Iteration Number

$P_{co} = -60 \text{ dB}$

$P_{co} = -20 \text{ dB!}$
Example #1

$P_{co} = -60dB$

$w_{co} = 1.0$

$w_{cr} = 0.0$

$P_{co} = -60dB$

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

$w_{cr} = 0.0$
Example#2

Co-Polarization Portion of Decision Function

Cross-Polarization Portion of Decision Function

Overall Decision Function

\[ P_{co} = P_{cr} = -60\text{dB} \]
\[ w_{co} = 1.0 \]
\[ w_{cr} = 1.0 \]
\[ F_{scale} = 23.32\text{ dB} \]
Example #2

\[ F_n = -36.8 \text{ dB} \]

\[ F_n = -68.3 \text{ dB} \]
Example#2

\[ F_n = -68.3 \text{ dB} \]

\[ F_n = -89.0 \text{ dB} \]

<table>
<thead>
<tr>
<th>SCAN SIZE</th>
<th>ACQUISITION “TIME”</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>( T_o )</td>
</tr>
<tr>
<td>91</td>
<td>0.83 ( T_o )</td>
</tr>
<tr>
<td>61</td>
<td>0.37 ( T_o )</td>
</tr>
</tbody>
</table>
• **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

\[ F_n = 20 \log \left\{ \max_{i,j} \{ w_{co}(\theta_i, \phi_j) f_{co}^n(\theta_i, \phi_j) \} \right\} + 20 \log \left\{ \max_{i,j} \{ w_{cr}(\theta_i, \phi_j) f_{cr}^n(\theta_i, \phi_j) \} \right\} \]

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

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


J.McCormick, S.F.Gregson & C.G.Parini, “Quantitative measures between antenna patterns”

*IEE Proceedings*, Dec.2005

Combinations of the Above
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.