FAST NEAR FIELD MEASUREMENTS OF ELONGATED ANTENNAS

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Abstract

A very fast characterization of elongated antennas is obtained using Near Field measurements. In the proposed innovative technique, starting from a traditional approach, the measurement area is progressively reduced up to obtain very small area but still correctly measuring directive radiation pattern and gain.
This paper highlights the experimental results on a linear array, including a comparison of the radiation pattern and gain obtained from Near Field and from traditional Far Field Test Range measurements. Both Near Field and Far Field measurements were conducted on Fusaro Plant MBDA facilities.

1 INTRODUCTION

In this work is described an innovative technique for fast determination of directive radiation pattern and gain of elongated antennas using Near Field methodology.
It is known that the relative far-field pattern of an antenna is readily available from near field measurements using either a planar, cylindrical or spherical scan surface. It doesn't seem to be nearly as clear that also absolute parameters, such as gain, can be obtained using few additional measurements. In this paper after a brief theoretical summary, experimental results from near-field/far-field measurements are reported and discussed.
The antenna under test (AUT) is a linear array on a ground plane. In a first phase it has been demonstrated that planar near field scans can be used to achieve accurate evaluation of directive pattern and gain. For a fully electromagnetic characterization a cylindrical scan can be employed.
In a second phase it has been proved that it is still possible to obtain correct determinations of directive pattern and gain reducing the scan plane to one twentieth of the starting plane, thus drastically reducing measurement times. Successful comparison between Near Field and traditional Far Field results are reported.
This work includes also an accurate experimental analysis devoted to the choice of the probe and to the evaluation of measurement errors with particular attentions to probe-antenna multiple reflections and scan area truncation.

2 THEORETICAL BACKGROUND

Three basic methods can be used in order to achieve absolute power gain from near-field measurements:

1. the direct gain measurement
2. the gain comparison technique
3. the three antenna measurement.

In all methods, three quantities enter into the calculation of the antenna gain. These are one or more sets of relative near field data (which furnish the relative reconstruction of far field pattern), the gain of a standard antenna (ST), and one or more power ratio or insertion loss measurements between probe and AUT.
In this work we used the *Gain Comparison* technique where the AUT's gain has been deduced from the known ST gain, without knowing the probe gain. In the case where the probe and AUT are polarization matched, the gain equation is simplified in:

$$G_{AUT}(k_{0x},k_{0y}) = \frac{\left(1-|\Gamma_{ST}|^2\right)}{\left(1-|\Gamma_{AUT}|^2\right)} \frac{IL(x_1,y_1,z_{1t})_{ST-probe}}{IL(x_0,y_0,z_{0t})_{AUT-probe}} \cdot \frac{\left|d_x d_y \sum_i B_{0\_AUT}(x_i,y_i,z_{0t}) e^{-j(k_{0x}x_i+k_{0y}y_i)}\right|^2}{\left|d'_x d'_y \sum_i B_{0\_ST}(x'_i,y'_i,z_{1t}) e^{-j(k_{0x}x'_i+k_{0y}y'_i)}\right|^2} G_{ST}(k_{0x},k_{0y})$$

Where G_{ST} *e* G_{AUT} are, respectively, the reflection coefficient of the ST and AUT, $IL(x_0,y_0,z_t)$ is the insertion loss between probe and AUT or ST; $B_0(x_i,y_i,z_t)$ represents the complex output of the probe in the points of the measurement surface; $G_{ST}(k_{0x},k_{0y})$ represents ST gain in K_0 direction. Although this approach has certain advantages, it can increase some error sources. For example, if the standard antenna and the AUT have quite different radiation patterns, truncation errors in $B_0(x_i,y_i,z_t)$ determination can be significant. This is illustrated and quantified experimentally in the following.

3 EXPERIMENTAL RESULTS FOR LARGE SCAN AREA

To correctly reconstruct far field pattern from near field measurements an experimental activity has been conducted to choose the more suitable probe for the AUT. The probe has been chosen aiming at minimizing multiple reflections probe-AUT, reducing room scattering, and particularly reducing truncation error on gain, beamwidth and beam pointing determinations. Different probes have been evaluated (two pyramidal horns and two open ended waveguides). The AUT is a linear array with directive pattern in the elevation plane. The reference scan area has been chosen in order to correctly reconstruct the directive pattern from –50° to +50°, while the roll pattern is supposed partially reconstructed.

3.1 Multiple reflections errors

Tests were performed to estimate the effects on the far field of multiple reflections interactions between the probe and the AUT. We carried out scans at several consecutive separation distances λ/8 apart. After phase correction, radiation patterns from single scans were averaged together to obtain the free error far field (fig. 1).
A complex subtraction of this average far field from each single scan far field, can give an estimate of the multiple reflections error spectrum.

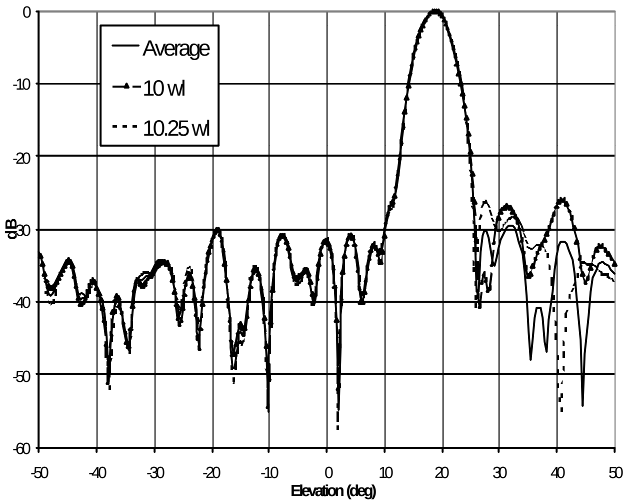

Fig.1-Far field pattern after averaging for multiple reflections (from 10l and 10.25l scans).

3.2 Truncation errors

Truncation of scan area has two effects. First, the far-field results are valid only within the angular region defined by the AUT, the scan area and by the separation distance. The larger scan area and the lower separation distance are, the bigger the validity region is. Second, truncation produces errors on far field pattern even within the "region of validity" as the neglected electromagnetic field at the boundary of scan area is not zero. The truncation errors effects on directivity determination can be seen from fig. 2 as function of scan area and for the different test probes. Thinking scan area as a **n**x**m** matrix, we reduce the number of columns (horizontal dimension) while taking fixed the vertical dimension.

For each probe it can be seen that reducing scan area, uncertainties on directivity determination increase (fig.2). In particular for the two pyramidal horns, at the reference scan area the truncation error on gain determination is limited to few tenths of dB while for open ended waveguides the error is large also for large scan areas.

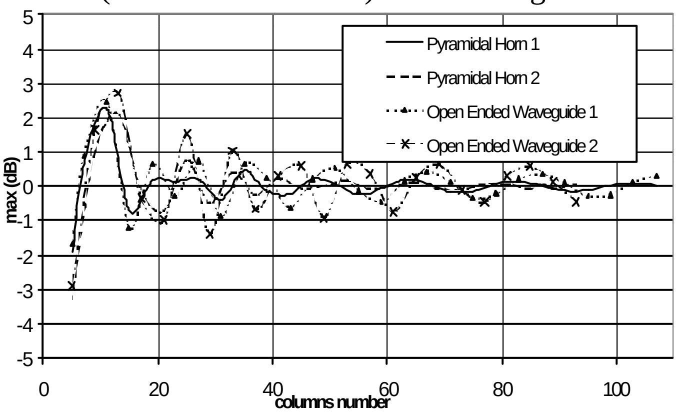

Fig.2-AUT normalized directivity vs scan area for different probes.

3.3 Near Field – Far Field patterns comparison

For the chosen scan area and probe Near Field measurements were performed. The comparison between radiation patterns from Near Field and Far Field test ranges are shown in the figure 3. The agreement is very good, with tiny differences on low sidelobes.

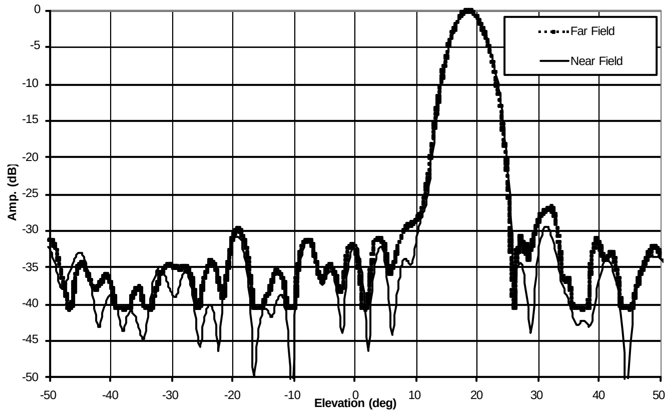

Fig.3-Radiation patterns from Near-Field and Far-Field test ranges.

3.4 Gain Determination

Gain determination of the AUT has been obtained using a Standard Gain Horn as Standard Antenna (ST). As the two antennas have quite different geometries and radiation patterns, also for the ST the reflection and truncation errors have been evaluated. At the chosen separation distance, the reflection errors on gain determination are low, while the effects of truncation error can be appreciated in the figure 4. It can be seen that for large scan areas, uncertainties on the ST gain determination can be neglected. For completeness in the same figure is reported the normalized gain for the AUT.

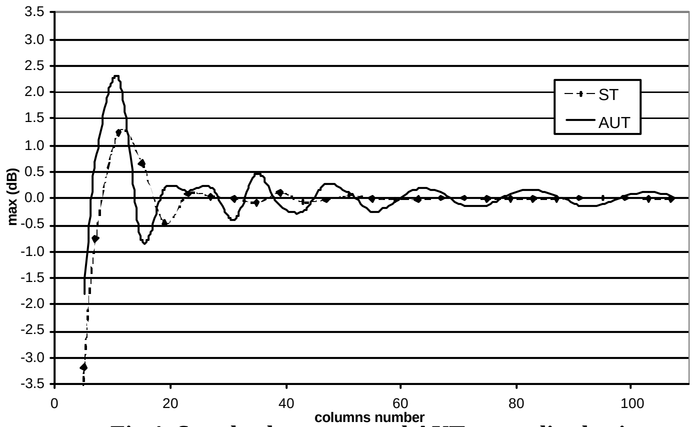

Fig.4- Standard antenna and AUT normalized gain vs scan area.

The uncertainties in gain determination using the *Comparison Technique* for large scan areas are very low (±0.1 dB) and due essentially to AUT (fig. 4).

For a meaningful sample of AUTs, Near Field and traditional Far Field test range gave comparable gain measurements.

4 EXPERIMENTAL RESULTS FOR SMALL SCAN AREA

The next step was to study the effect of scan area reduction on directive pattern and gain determination. The goal was to sharply reduce horizontal dimension of scan area without loosing accuracy for the desired parameters. The effect on pattern reconstruction, beamwidth, direction pointing and gain have been evaluated.

4.1 Pattern Reconstruction

In fig. 5 are reported the far field patterns reconstructed from a complete and from the final scan area. Progressive scan reductions have been evaluated by SW procedure. Only few columns taken into account give a very good reconstruction of directive pattern, which results nearly equal to that obtained from a complete measurement with small differences on far side lobes.

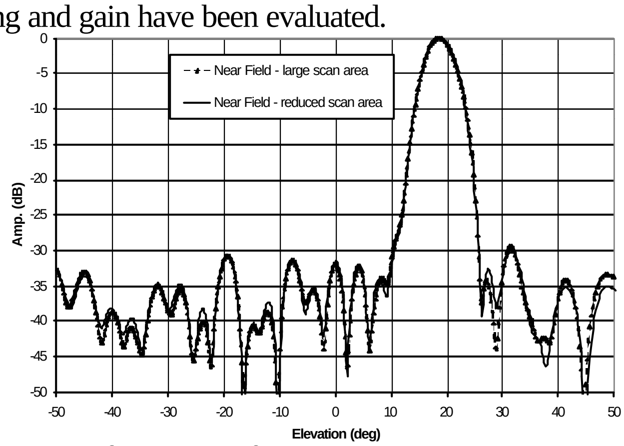

Fig.5-Far field patterns from large and small scan area (5%).

4.2 Gain Determination

For a scan area reduced to the 5% of the large scan area, the AUT and ST normalized gains are quite different (see Fig. 4). This result shows that it is not possible to use *Comparison Technique* on truncated measurements when AUT and ST have very different geometries and patterns. Nevertheless the *Comparison Technique* can still be utilised for truncated measurements if the SGH antenna employed as Standard (ST) is replaced by an antenna of the same kind as AUT. The latter, previously fully characterized by a complete measurement, can be used as "Standard" for next antennas of the same family. To show the feasibility of this procedure in the following Fig. 6 are reported the normalized gains as a function of truncation area for three antennas: AUT1 used as ST, AUT2 of the same type but on a mismatched load, and finally AUT3 with partially blocked radiating aperture. The normalized gain vs scan area is practically the same for the tested antennas, so a correct determination of a ST gain allows a correct relative determination of gain on the antennas of the same family.

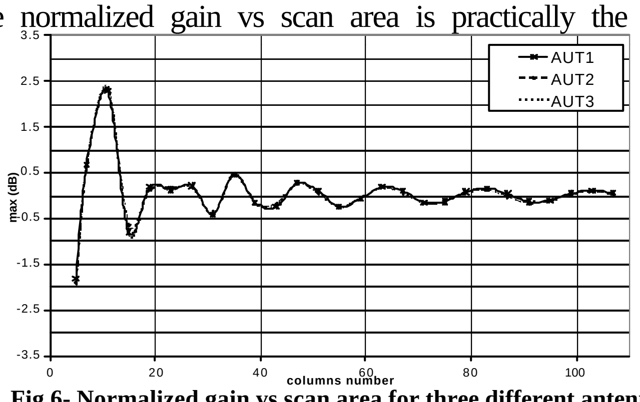

Fig.6- Normalized gain vs scan area for three different antennas.

5 CONCLUSIONS

Deep experimental activities on Elongated Antennas have been completed. It has been demonstrated that it is possible to correctly characterize antennas of the same type with truncated and very fast Near Field measurements reducing dramatically measurement times.

Costs and times saving are very important features for routine testing of such antennas.

6 REFERENCES

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