ON THE IMPACT OF NON-RECTANGULAR TWO DIMENSIONAL NEAR-FIELD FILTER FUNCTIONS IN PLANAR NEAR-FIELD ANTENNA MEASUREMENTS

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ABSTRACT

In this paper a circular planar near-field scan region is considered as an alternative to the commonly used rectangular boundary. It is shown how the selection of this alternative boundary can reduce test time and also to what extent the alternative truncation boundary will affect far-field accuracy. It is also shown how well known single dimensional filter functions can be applied over a two-dimensional region of test and how these attenuate the truncation effect. The boundary and filter functions are applied to measured data sets, acquisition time reduction is demonstrated and the impact on far-field radiation pattern integrity in assessed.

Keywords: Antenna measurements, Planar near-field, Measurement errors, Data acquisition, Range evaluation.

1 Introduction

Planar near-field acquisition is usually restricted to a rectangular scanning area orthogonal to the z-axis of the scanner [1]. This selection is simple and convenient and the user determines the extent of the plane (i.e. total surface area) based on near-field field intensity and maximum far-field angle of interest [2]. Reduction of this scan area leads to undesired truncation effects that introduce far-field errors and these can be controlled through special rectangular filter functions [3]. However, the primary objective of the acquisition is to capture a representative image of the electromagnetic energy crossing the plane and since this distribution is rarely rectangular in shape, the shape of the scan plane can be optimized to reduce data acquisition times. In [4] a constant field intensity contour (CFIC) method was presented by the author to reduce planar near-field acquisition time by truncation of the scan area using optimized non-rectangular scan planes. This technique offers obvious acquisition time reduction over the traditional rectangular technique but still suffers from truncation effects.

In this paper the application of circular scan plane boundaries in conjunction with two-dimensional filter functions [5] are investigated as a way to reduce planar near-field test times and to control the impact of truncation. Typical test time reductions are shown as well as far-field induced error levels, using actual measured near-field data.

2 Scan Plane Reduction Methodology

A typical planar near-field data set, acquired over a rectangular region, contains amplitude and phase distributions for two orthogonal polarization components. The amplitude distribution for an example data set (diagonal pyramidal standard gain horn) is shown in Figure 1.

Reduction of the total acquisition region can be performed by simply reducing the linear limits of the near-field region. An example of this type of scan plane reduction is shown in Figure 2 where a uniform section of data is omitted along the circumference of the data set. Although not explicitly shown here, this type of truncation is also applied to the orthogonal polarization data set. The estimated data acquisition time reduction as a result of the truncation shown in this particular example is 40%.

This type of rectangular truncation as well as a more sophisticated Constant Field Intensity Contour (CFIC) technique was reported in [4]. However, it was found that the discontinuity of the truncation function introduced errors in the far-field data that were prohibitive. In the results presented below a circular region of truncation is considered as an alternative to the rectangular region. However, filter functions are also used to soften the effect of the truncation discontinuity.

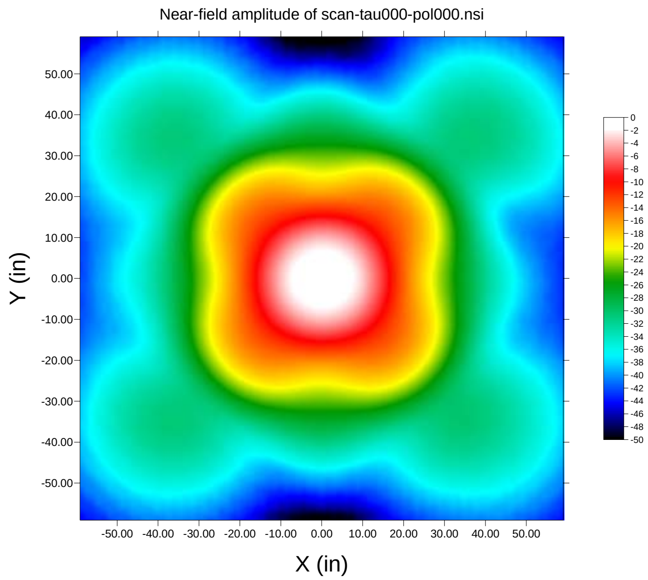

Figure 1: Near-field field intensity for polarization 1 – Case #1.

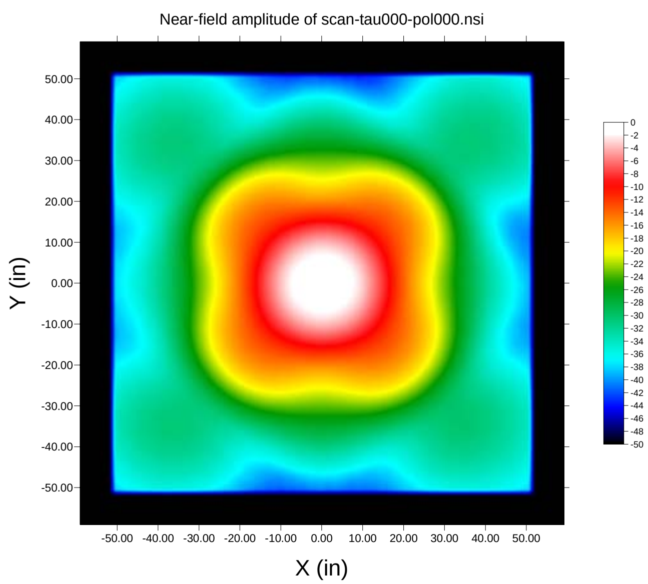

Figure 2: Truncation of the data set shown in Figure 1 along a rectangular region. (Rectangular scan plane boundary with uniform weighting applied – 40% scan time reduction.)

If the near-field field intensity acquired over a planar region with spatial variables *(x,y)* is denoted by *E(x,y)* then the truncation/filtering process can be described as:

$$E'(x,y) = w(x,y)E(x,y)$$

where *w(x,y)* is a two-dimensional filter function controlling the truncation boundary and weighting. Two truncation functions are considered in this instance, the rectangular function:

$$w(x,y) = w_{U/B/H} \text{ for } |x| < x'' \textit{ and } |y| < y''$$
$$w(x,y) = 0 \text{ for } |x| > x''$$
$$w(x,y) = 0 \text{ for } |y| > y''$$

And the elliptical function (reduced to a circular function in this case):

$$w(x,y) = w_{U/B/H} \text{ for } \frac{\mathrm{y}^2}{x''^2} + \frac{\mathrm{x}^2}{y''^2} \le 1$$
$$w(x,y) = 0 \text{ for } \frac{\mathrm{y}^2}{x''^2} + \frac{\mathrm{x}^2}{y''^2} > 1$$

where 2x’’ is the width of the rectangular or elliptical truncation area and 2y’’ is the height. Both are assumed to be centered on the coordinate system origin. (Note that for the examples considered in this paper x’’=y’’, reducing the elliptical scan region to a circular region.)

Three weighting functions are considered here, the Uniform function, the Bartlett function and the Hanning function [5]. Each of these can be defined in a one dimensional sense as follows.

Uniform function:

$$w_U(x) = 1$$

Bartlett (triangular) function:

$$w_B(x) = 0 \text{ for } |x| > x''$$
$$w_B(x) = \frac{x - x''}{l} \text{ for } -x'' \le x \le -x'' + l$$
$$w_B(x) = 1 \text{ for } |x| < x'' - l$$
$$w_B(x) = -\frac{x - x''}{l} \text{ for } x'' - l \le x \le x''$$

Hanning function:

$$w_H(x) = 0 \text{ for } |x| > x''$$
$$w_H(x) = \sin^2\left[\frac{\pi(x + x'')}{2l}\right] \text{ for } -x'' \le x \le -x'' + l$$
$$w_H(x) = 1 \text{ for } |x| < x'' - l$$
$$w_H(x) = \sin^2\left[\frac{\pi(x - x'')}{2l}\right] \text{ for } x'' - l \le x \le x''$$

where *l* is the linear transition region of the weighting function.

Application of these functions for a rectangular truncation region can be achieved by applying the weighting function independently in the x and y directions, which makes the implementation trivial. Application for an elliptical region can be achieved by using the relationship [5]:

$$w(x, y) = w\left(\sqrt{x^2 + y^2}\right)$$

which provides a technique for generalizing one-dimensional filter functions to two dimensions. Using this formulation the near-field data of Figure 1 can be truncated over a rectangular or a circular region and the discontinuity at the boundary can be softened by using a Bartlett or a Hanning weighting function. A single horizontal data cut through the center of Figure 2 is shown below in Figure 3.

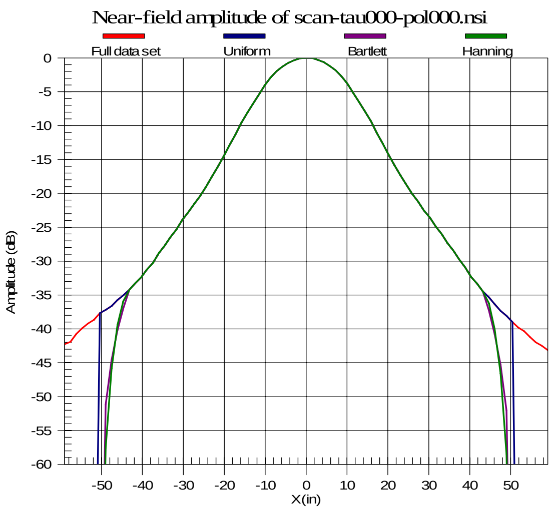

Figure 3: Near-field amplitude distribution for the original data set, uniform -, Bartlett - and Hanning weighted truncated data sets are shown.

The original data set, the Bartlett and the Hanning weighted cases are also shown for comparison (in these cases *l* is selected to be 2λ).

3 Measured Data Test Cases

In evaluating the truncation boundaries and weighting functions described above, two test data sets are considered. The first data set (Case #1) is for a diagonal standard gain horn (data already presented in Section 2) and the second (Case #2) is for a Gregorian reflector antenna. For both of these test cases six parametric studies were conducted. These are:

Test #	Truncation region	Weighting
1	Rectangular	Uniform
2	Rectangular	Bartlett
3	Rectangular	Hanning
4	Circular	Uniform
5	Circular	Bartlett
6	Circular	Hanning

For Case #1, extraction of the far-field radiation patterns from both the full and rectangular truncated data (Figures 1 & 2) sets using Hanning weighting, provides radiation patterns as shown in Figure 4. These patterns clearly show the impact of the truncation and an error pattern can be calculated as shown, with a maximum value of roughly –46dB below the beam peak value.

Extraction of the far-field radiation patterns from both the full and circular truncated (shown below in Figure 6) data sets using Hanning weighting, provides comparative radiation patterns. These patterns also show the impact of the truncation and an error pattern can be calculated with a maximum value of roughly –50dB below the beam peak value. Although slightly lower than that for the rectangular truncation case, the difference is not significant.

When considering gain variation as a function of truncation, Figures 6 & 7 result for the rectangular and circular truncation cases respectively. Both of these graphs demonstrate the significance of using a non-uniform weighting on the near-field data and also highlight the fact that this becomes more significant as the acquisition region decreases in size.

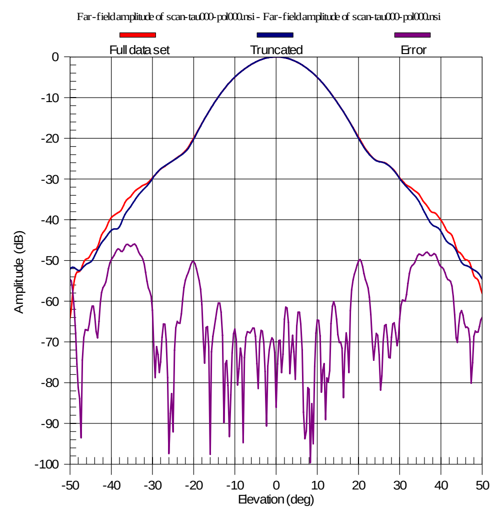

Figure 4: Case #1/Test #3 - Far-field elevation pattern resulting from Figure 3 data - rectangular scan plane boundary with two-dimensional Hanning weighting.

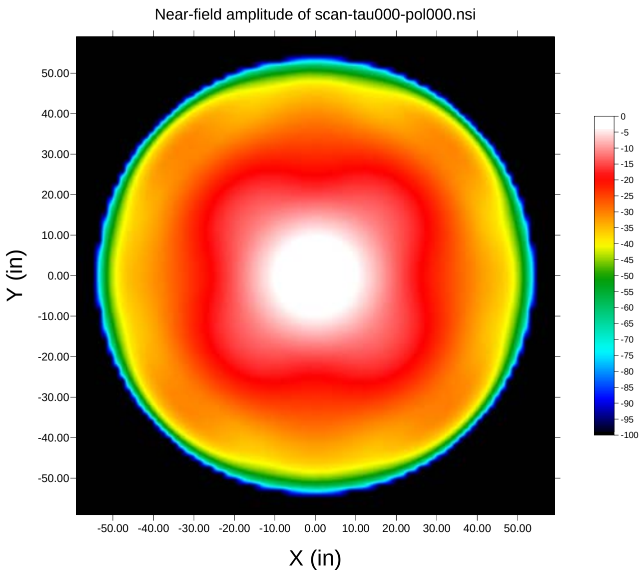

Figure 5: Circular scan plane boundary with two-dimensional Hanning weighting applied – 40% scan time reduction.

The graphs show a 0.25dB p-p and a 0.35dB p-p variation for the rectangular and circular truncation cases respectively when using uniform weighting. These numbers reduce to roughly 0.1dB p-p for both the rectangular and circular truncation cases when using Hanning weighting.

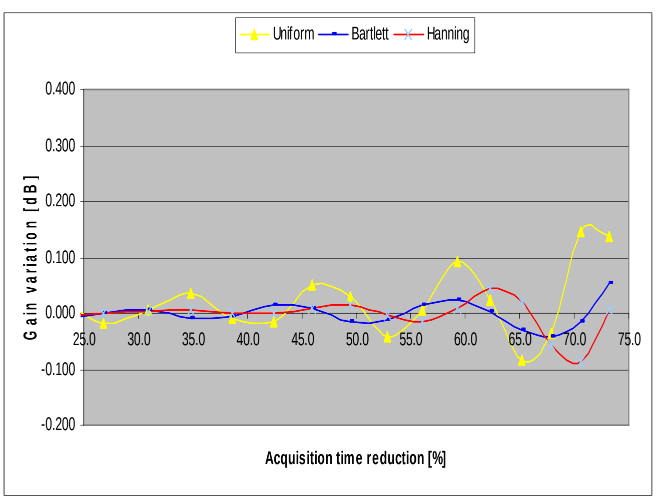

Figure 6: Case #1: AUT gain variation shown as a function of acquisition time reduction - rectangular scan plane boundary using Uniform, Bartlett or Hanning weighting.

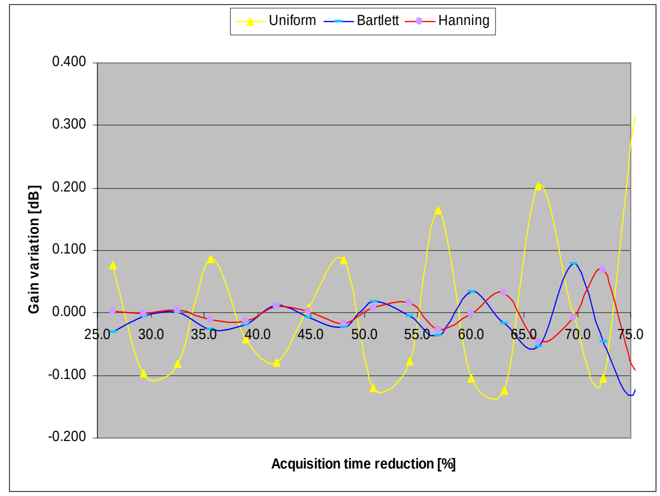

Figure 7: Case #1: AUT gain variation shown as a function of acquisition time reduction - circular scan plane boundary using Uniform, Bartlett or Hanning weighting.

For Case #2 the near-field amplitude distribution of the dominant polarization is shown in Figure 8. Visual inspection of this distribution suggests that the rectangular scan plane is not optimal for the near-field distribution of the particular antenna.

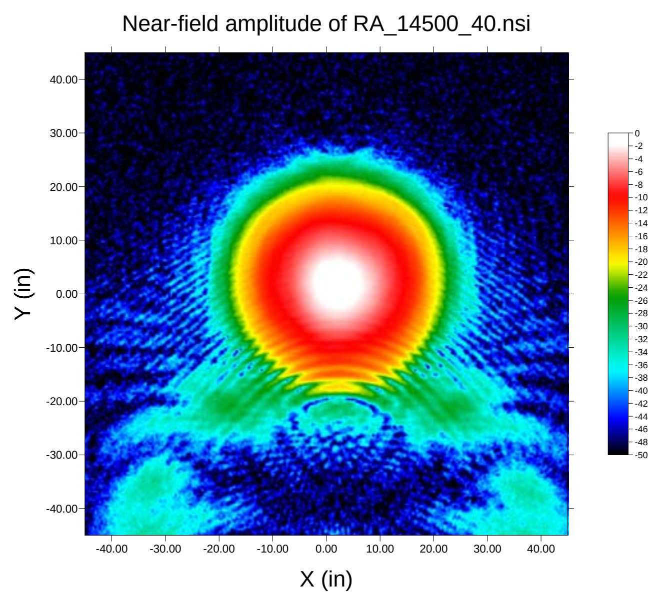

Figure 8: Near-field field intensity for polarization 1 – Case #2.

Rectangular truncation corresponding to roughly a 60% acquisition time reduction is shown in Figure 9. The comparative circular truncation, results in the truncated data set shown in Figure 10. The estimated data acquisition time reduction as a result of this truncation is also estimated at 60%.

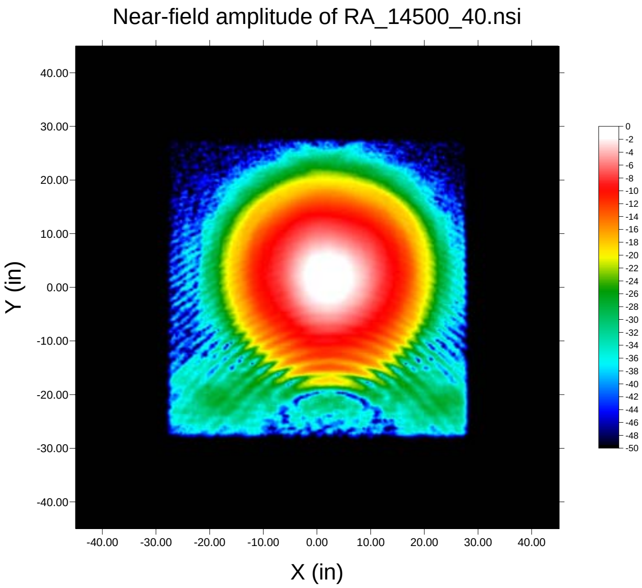

Figure 9: Rectangular scan plane boundary with two-dimensional Hanning filter applied – 60% scan time reduction.

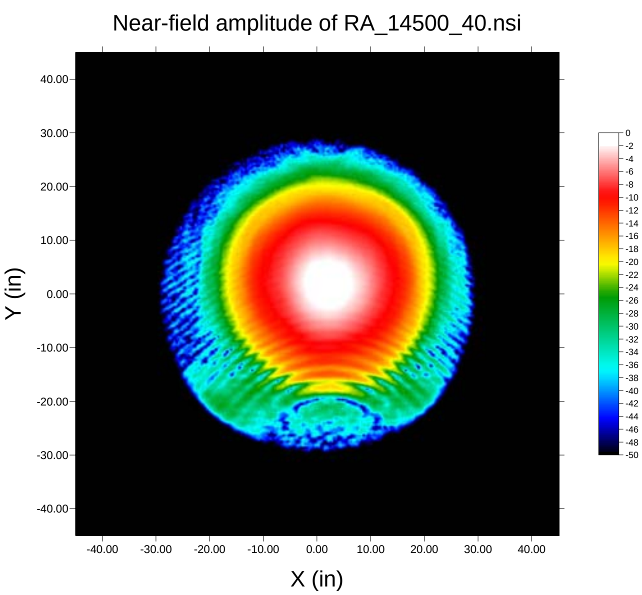

Figure 10: Circular scan plane boundary with two-dimensional Hanning filter applied – 60% scan time reduction.

Extraction of the far-field radiation patterns from both the full and rectangular truncated data sets (Figures 8 & 9 respectively), provides comparative radiation patterns as shown in Figure 11. These patterns show the impact of the truncation and an error pattern with a maximum value of roughly –56dB below the beam peak value results.

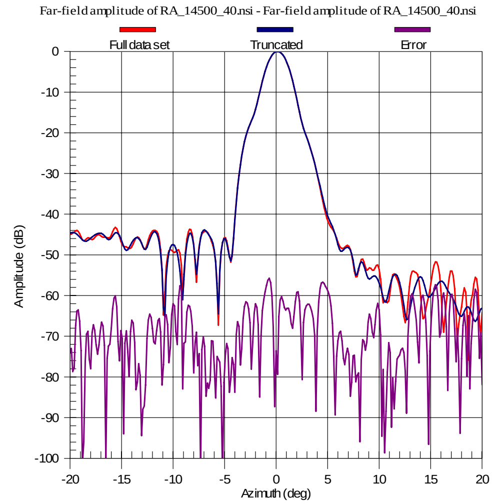

Figure 11: Case #2/Test #3 - Far-field azimuth pattern resulting from Figure 9 data - rectangular scan plane boundary with two-dimensional Hanning weighting.

Extraction of the far-field radiation patterns from the circular truncated data sets (Figure 10), provides similar radiation patterns with an identical maximum error value of roughly –56dB below the beam peak.

When again considering gain variation as a function of truncation, Figures 12 & 13 result for the rectangular and circular truncation cases respectively. Both of these graphs demonstrate that the reduction in gain variation by using a non-uniform weighting function is not significant in this instance and that the circular truncation region is of much greater significance here. By selecting a rectangular truncation region, acquisition time can be reduced by up to 60% before a significant increase in gain variation is detected. Using the circular truncation region, acquisition time can be reduced by up to 75% before the same increase in gain variation is detected.

It is also worthwhile to note that the lateral offset between the uniform weighting curve and the Bartlett and Hanning curves is due to the finite extent of the filter transition region *l*. The fact that there is no significant difference between the Bartlett and Hanning weightings in this case, is due to the very steep near-field amplitude slope at the edges of the AUT main beam region.

By applying both of the truncation boundaries in a progressive manner, maximum and average far-field radiation pattern errors as a result of the truncation can be extracted and shown as a function of acquisition time reduction. Figure 14 below shows the co-polar maximum error values for both truncation boundaries, uniform and Hanning weighting functions.

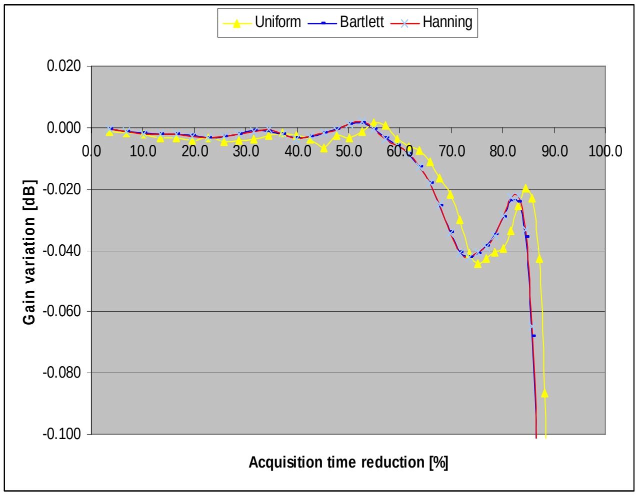

Figure 12: AUT gain variation shown as a function of acquisition time reduction. Rectangular scan plane boundary using Uniform, Bartlett or Hanning filtering.

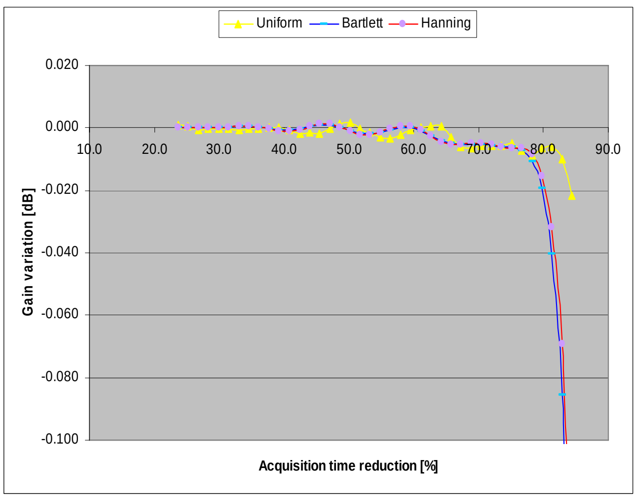

Figure 13: AUT gain variation shown as a function of acquisition time reduction. Circular scan plane boundary using Uniform, Bartlett or Hanning filtering.

In this particular instance the advantage of the circular truncation technique is evident from the error curves and this is due to the circular nature of the particular AUT near-field distribution. The error curves show that the weighting function does not play a significant role in this case and that switching from a rectangular scan boundary to a circular boundary can offer roughly an additional 20% acquisition time reduction.

4 Conclusions

It has been shown how circular scan plane boundaries can be used as an alternative to the conventional rectangular scan plane boundaries. It has also been demonstrated that such truncation has to be combined with two-dimensional filter functions in order to reduce the impact of the truncation boundary discontinuity.

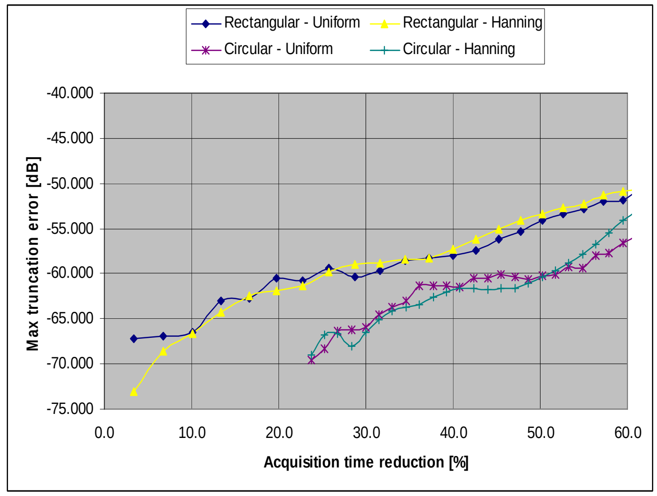

Figure 14: Maximum far-field co-polar errors as a function of acquisition time reduction using the rectangular and circular scan plane boundaries: Case #2.

Although the use of a circular boundary has significant test time reduction advantages in some cases, it does not hold true in all cases since it is a function of the specific AUT near-field distribution. In all cases considered here, the use of a two-dimensional filter function (weighting function) proved to be advantageous and the use of these filter functions for any type of scan plane boundary should be considered as an enhancement for planar near-field testing.

5 References

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