SCAN PLANE REDUCTION TECHNIQUES FOR PLANAR NEAR-FIELD ANTENNA MEASUREMENTS

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ABSTRACT

In this paper two planar near-field scan plane reduction techniques are considered and results are presented. It is shown how truncation based on field intensity contours, instead of simple geometric truncation can in some cases improve the efficiency of the truncation process. Both techniques are applied to measured data sets and it is shown how these methods can be used to reduce data acquisition times while also assessing the impact of the total acquisition surface reduction on the far-field radiation pattern integrity.

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]. 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 this paper a rectangular scan plane reduction technique is compared to a constant field intensity contour (CFIC) method. Both techniques are progressively applied to measured planar near-field data sets and the reduced data sets and corresponding far-field induced truncation error values are extracted. The truncation errors are shown as a function of the percentage acquisition time reduction. In all cases the maximum and average co-polar and cross-polar radiation pattern errors are extracted on both principal and both diagonal planes, in order to derive a figure of merit as performance indicator.

The objective of this paper is to show how scan plane limits may be optimized to reduce test times while still maintaining control of the associated far-field truncation error. The end result improves the efficiency of planar near-field data acquisition (i.e. reduces overall test time) and provides the user with a measure of the associated error introduced.

A limitation of the methodology being presented is that an initial large measured data set is still required to enable the associated post processing and analysis. The test time reduction can therefore be exploited in subsequent data acquisitions, but an overall reduction in scanner size will not result. An advantage of this methodology is that the larger initial data set can be used to obtain an estimate of the leakage error [3,4] forming part of the planar near-field measurement.

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 distributions for an example data set (diagonal pyramidal standard gain horn) are shown in Figures 1 & 2. From these amplitude distributions it is clear that regions of low field intensity (regions in black represent field intensity values <50dB below the peak) is being covered during the acquisition process while this data may not contribute significantly to the accuracy of the far-field result. A technique to reduce data acquisition in these regions will have obvious advantages.

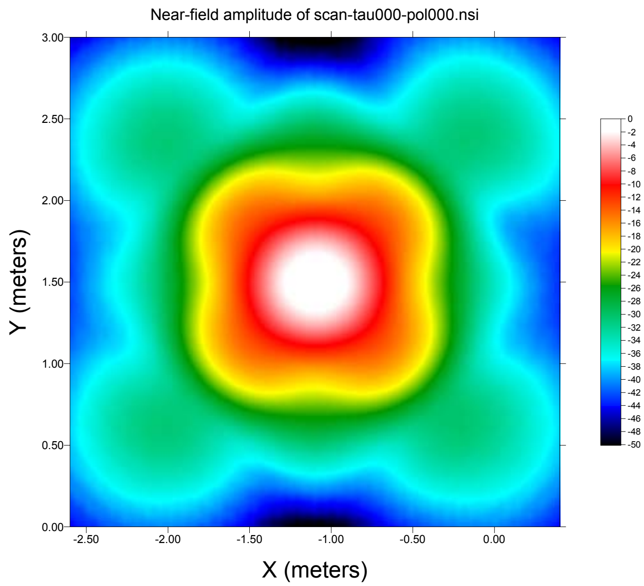

Figure 1: Near-field field intensity for polarization 1.

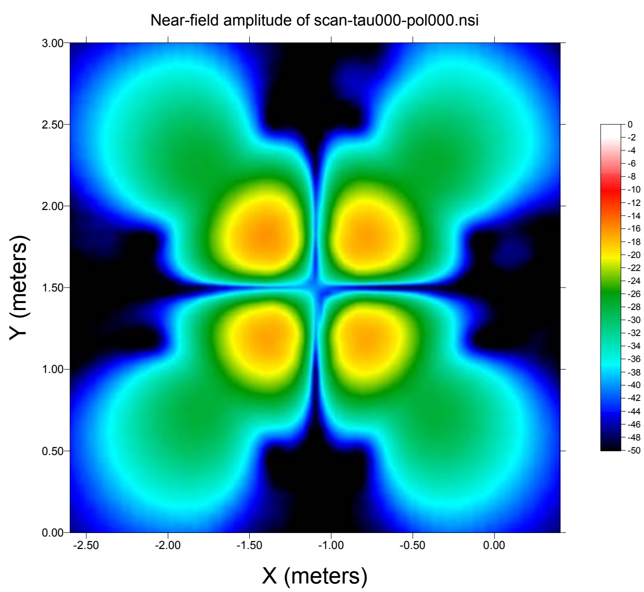

Figure 2: Near-field field intensity for polarization 2.

Traditionally scan plane truncation is performed by geometric reduction of the rectangular scan area. This technique relies heavily on the judgment of the operator and is often times driven by the truncation error observed in the principal plane radiation patterns only. An example of this type of scan plane reduction is shown in Figure 3 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 10%.

Visual inspection of Figure 3 suggests that the rectangular truncation technique is not optimal for the near-field distribution of the particular antenna considered. A potential improvement is to truncate the scan plane based on field intensity level and in the cases considered here, this is done along the y-axis. (The reason for this selection is that overall truncation will reduce the data set even further, but will not translate to a data acquisition time reduction, simply based on the fact that the mechanical motion of a near-field scanner is still required to acquire all data points of interest along a single y-axis data column.)

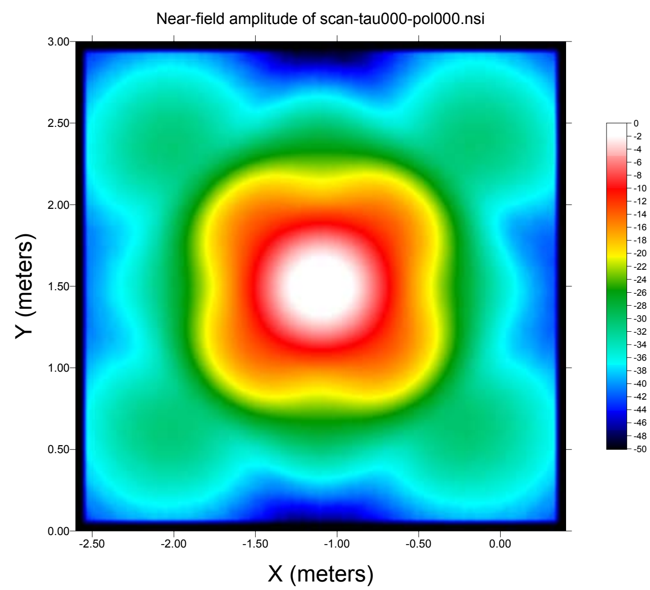

Figure 3: Truncation of the data set shown in Figure 1 along a rectangular region.

When applying this CFIC truncation on the near-field data set shown in Figure 1, the truncated data set shown in Figure 4 results. The truncation region clearly follows a contour of constant field intensity. The estimated data acquisition time reduction for this particular level of truncation shown in Figure 4, is also 10%. (Two cases of similar acquisition time reductions were selected to allow for valid comparison of far-field radiation pattern errors.)

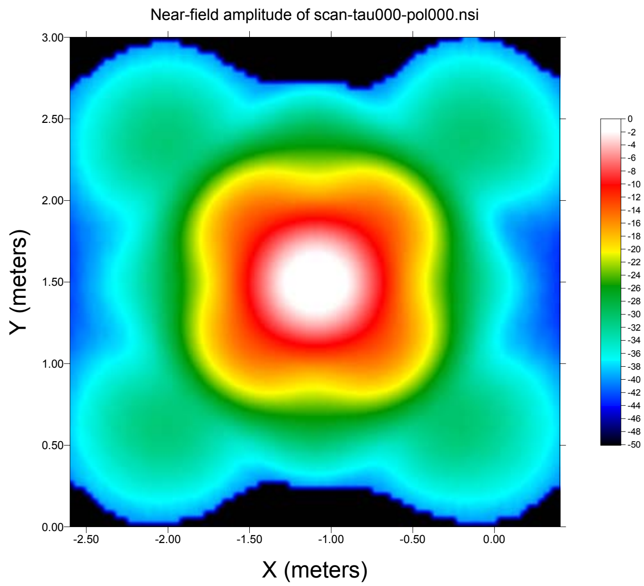

Figure 4: Truncation of the data set shown in Figure 1 along a CFIC. Scanning along y-axis considered.

3 Measured Data Test Cases

In evaluating the two truncation methods 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. In both cases the impact of the rectangular and CFIC truncation techniques are compared.

For Case #1, extraction of the far-field radiation patterns from both the full and rectangular truncated data sets (Figures 1 & 3 respectively), provides radiation patterns as shown in Figure 5. These patterns clearly show the impact of the truncation and an error pattern can be calculated as shown, with a maximum value of roughly –48dB below the beam peak value.

Extraction of the far-field radiation patterns from both the full and CFIC truncated data sets (Figures 1 & 4 respectively), provides comparative radiation patterns as shown in Figure 6. These patterns also show the impact of the truncation and an error pattern can be calculated as shown, with a maximum value of roughly –52dB below the beam peak value, but an average error value of roughly 5dB lower than the rectangular truncated case.

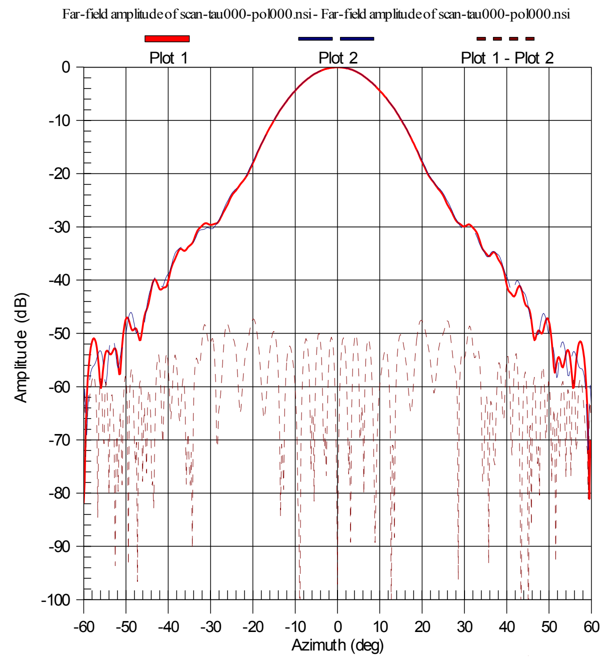

Figure 5: Case #1 - Far-field radiation patterns and error level for full and rectangular truncated data sets.

Figures 5 & 6 therefore show a lower average induced error level for the CFIC technique than for the rectangular truncation technique, while the acquisition time reduction is the same.

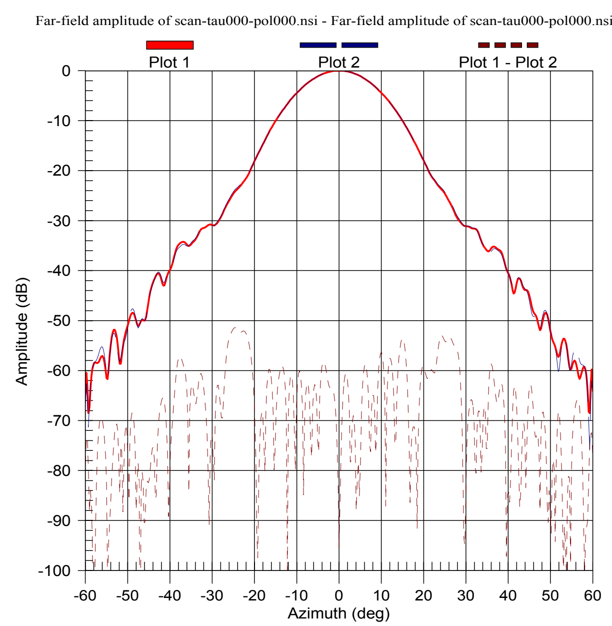

Figure 6: Case #1 - Far-field radiation patterns and error level for full and CFIC truncated data sets.

By applying both of the truncation techniques 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 7 below shows the co-polar maximum and average error values for both truncation methods (error curves for the cross-polar patterns show no benefit of one method over the other). Note that the rectangular truncation technique results in a discrete 4.5% acquisition time reduction by the omission of single rows and columns of data around the circumference of the data set. The fairly steep slope of the error curves also suggest that the data set considered in this case does not contain large areas of negligible energy and therefore the total acquisition time reduction through truncation is not significant unless a large truncation error can be tolerated. Of the two methods the CFIC truncation technique provides the more efficient result.

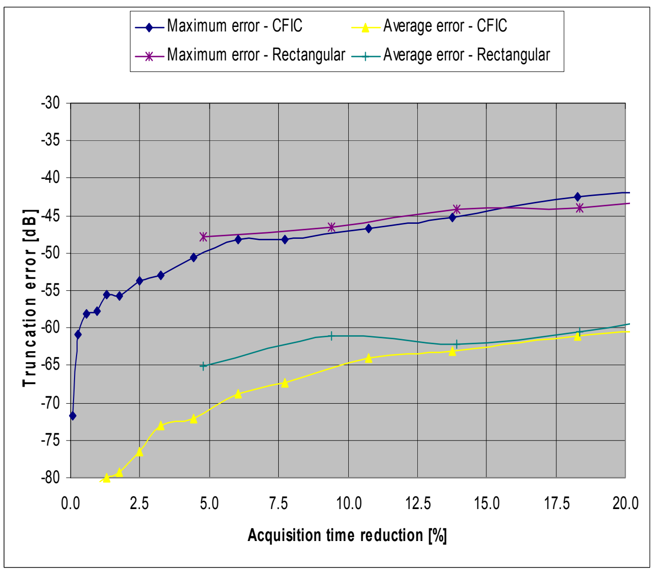

Figure 7: Maximum and average far-field co-polar errors as a function of acquisition time reduction using the rectangular and CFIC truncation techniques: Case #1.

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

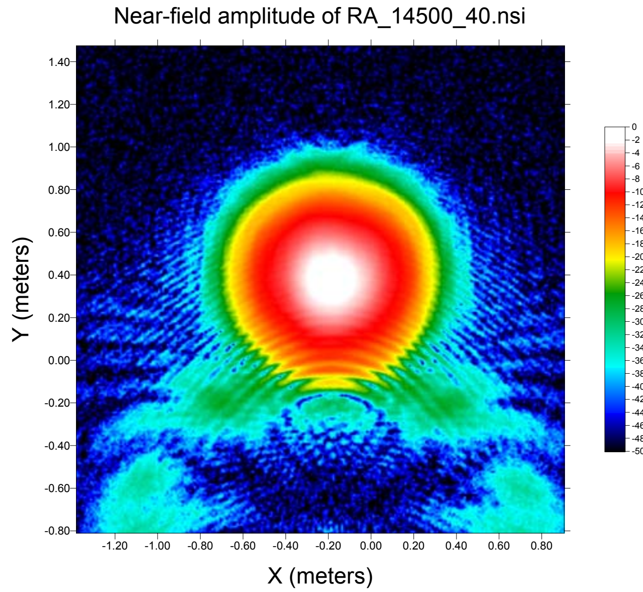

Figure 8: Near-field field intensity for polarization 1 – Case #2.

Rectangular truncation corresponding to roughly a 20% acquisition time reduction is shown in Figure 9. The comparative CFIC truncation along the y-axis, 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 20%.

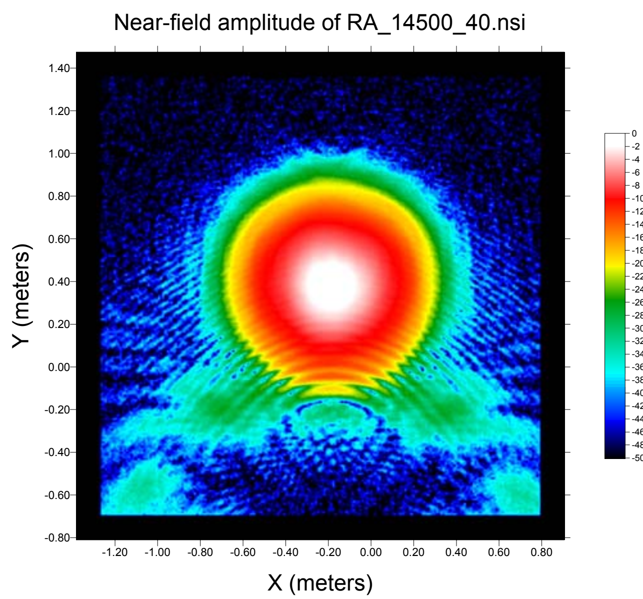

Figure 9: Truncation of the data set shown in Figure 8 along a rectangular region.

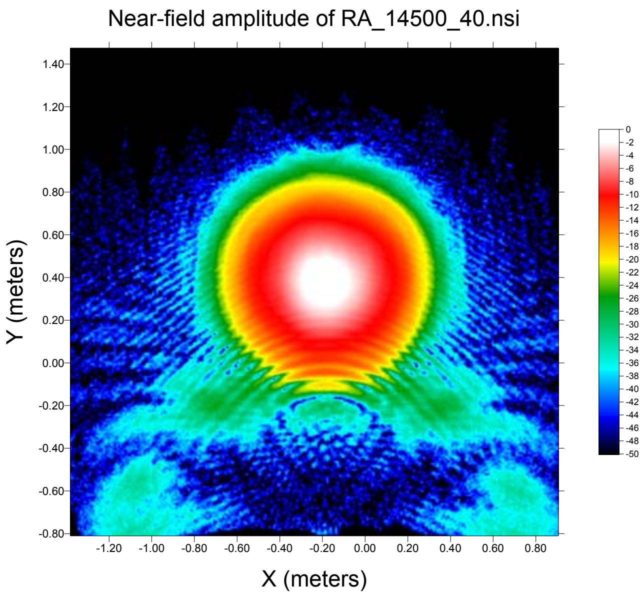

Figure 10: Truncation of the data set shown in Figure 8 along a CFIC. Scanning along y-axis considered.

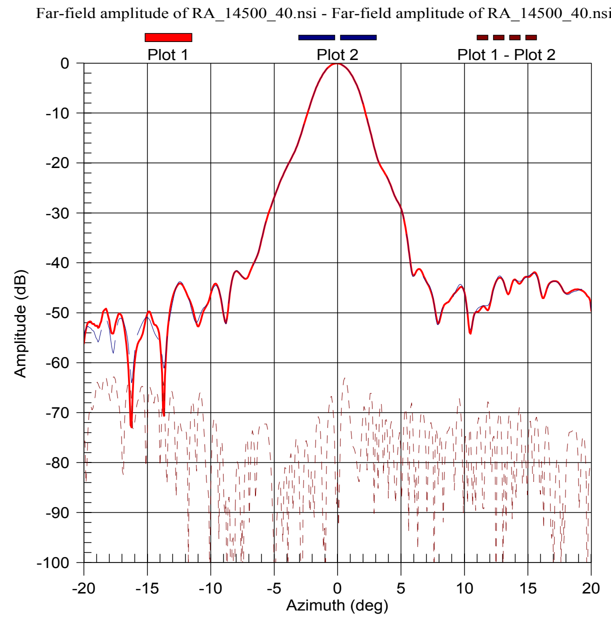

Figure 11: Case #2 - Far-field radiation patterns and error level for full and rectangular truncated data sets.

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 –62dB below the beam peak value results.

Extraction of the far-field radiation patterns from the full and CFIC truncated data sets (Figures 8 & 10 respectively), provides the radiation patterns shown in Figure 12. A maximum error value of roughly –66dB below the beam peak and an average error of about 3dB below that of the rectangular truncated case are noted.

By again applying both of the truncation techniques in a progressive manner, maximum far-field radiation pattern errors as a result of the truncation can be extracted and are shown in Figure 13. In this particular instance the advantage of the CFIC truncation technique is evident from the average error curves but the technique clearly deteriorates for higher levels of field intensity truncation.

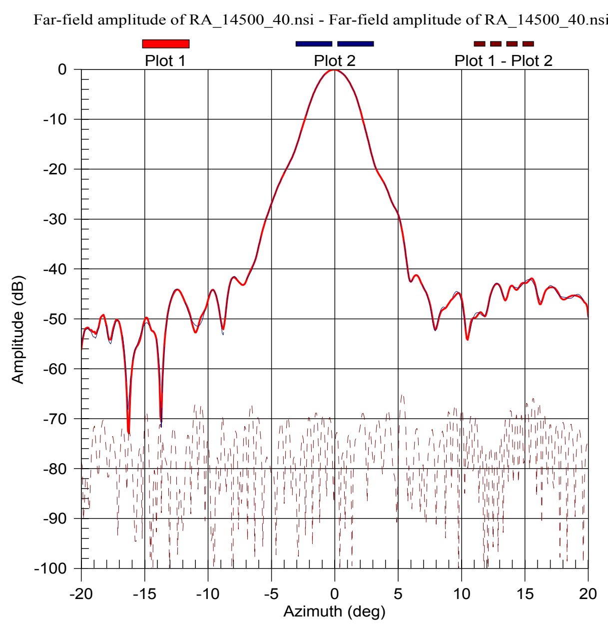

Figure 12: Case #2 - Far-field radiation patterns and error level for full and CFIC truncated data sets.

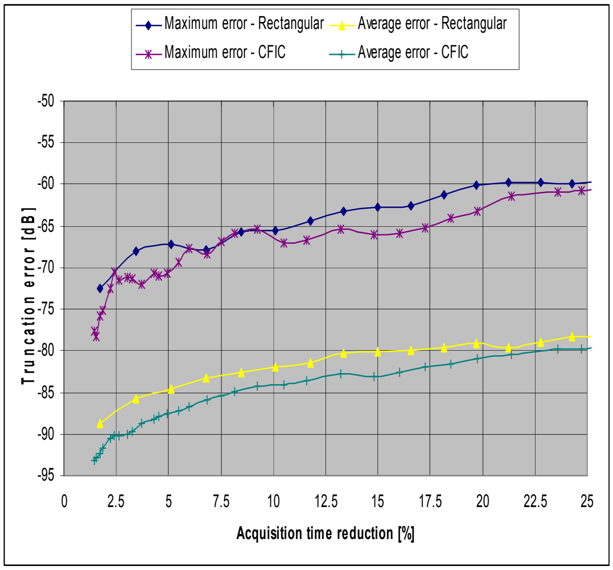

Figure 13: Maximum and average far-field co-polar errors as a function of acquisition time reduction using the rectangular and CFIC truncation techniques: Case #2.

4 Conclusions

A technique has been presented to reduce planar near-field acquisition time by truncation of the scan area. The limits of truncation are based on a constant field intensity contour (CFIC). The technique appears to offer advantages over the traditional rectangular truncation technique.

Comparative data has been presented for the rectangular scan plane reduction technique and the CFIC truncation method. Typical expected acquisition time reductions are shown, although this will vary depending on the initial scan plane size and specific AUT considered.

The results show how scan plane limits may be optimized to reduce test times while still maintaining control of the associated far-field truncation error. A limitation of the methodology presented here is that an initial data acquisition over a large region, is still required. The techniques presented here can then be applied to reduce the acquisition time for subsequent measurements.

5 References

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