EXTENDING THE ANGULAR COVERAGE OF PLANAR NEAR-FIELD MEASUREMENTS BY COMBINING PATTERNS FROM TWO OR MORE ANTENNA ORIENTATIONS

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Abstract

The angular coverage of planar near-field measurements is limited by the size of the scan plane, and the "region of validity" is defined by the angle between the edge of the AUT and the edge of the scan plane. In some applications, results are required over a larger angular region than is possible with the available scanner. The angular coverage can be increased by rotating the antenna and repeating the measurement. The results of the two measurements are then combined. Successful combination depends on using both the coordinate system and vector components that are appropriate for the antenna rotation.

In general for a single antenna orientation, any coordinate system can be used with any vector components, but when combining or comparing patterns for two antenna rotations, the axis of rotation must be the polar axis and the vector components must correspond to that coordinate system. Measurements results will be used to demonstrate the proper choice of coordinates and components and to illustrate potential problems that may arise.

Keywords: Antenna Measurements, Near-field, Planar, Pattern, Coordinate Systems

1. Introduction

An antenna coordinate system is implicit in almost every antenna measurement. Terms such as pattern, main and cross-component, beam pointing and peak gain, imply the definition of directions and/or vector field components which require a coordinate system. Reference is often made to **the** cross-component of an antenna as if there is a unique definition of such a quantity when in fact the cross-component as well as the main component will depend on which coordinate system is used and how it is oriented with respect to the antenna. In a previous paper[1] the authors defined three spherical coordinate systems and four sets of vector components associated with these coordinates. The rotator systems associated with these coordinate systems were also identified. For reference, the three coordinate systems are shown in Figures 1-3.

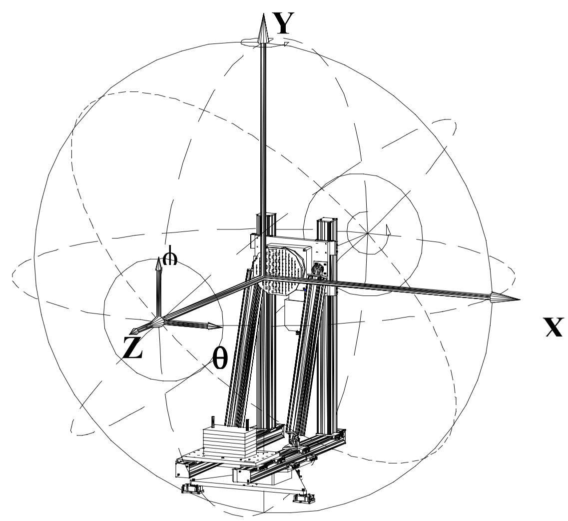

Figure 1 Theta Phi coordinate system and vector components

The θ and ϕ vector components shown in Figure 1 are defined along the lines of constant ϕ and θ. The Ludwig-3 vector components are derived from the θ and ϕ components by rotating the field vectors about the direction of propogation by the angle ϕ. These are referred to as the **h** and **v** components since they are approximately parallel to the x and y axes over most of the sphere.

The second spherical coordinate system is illustrated in Figure 2. In this case the polar axis is coincident with the y-axis and it is referred to as the Azimuth over Elevation system and the vector components are denoted by **A** and **E**.

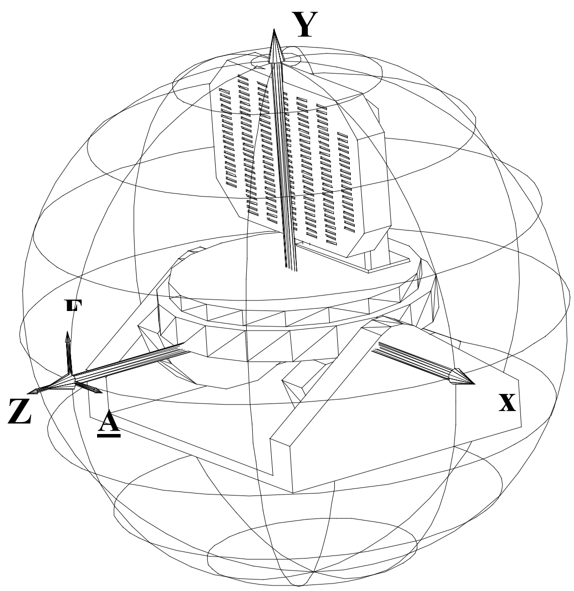

Figure 2 Azimuth over elevation coordinate system and the associated vectors A and E.

The third coordinate system is shown in Figure 3. The polar axis is coincident with the x-axis and it is referred to as the elevation over azimuth system and the corresponding

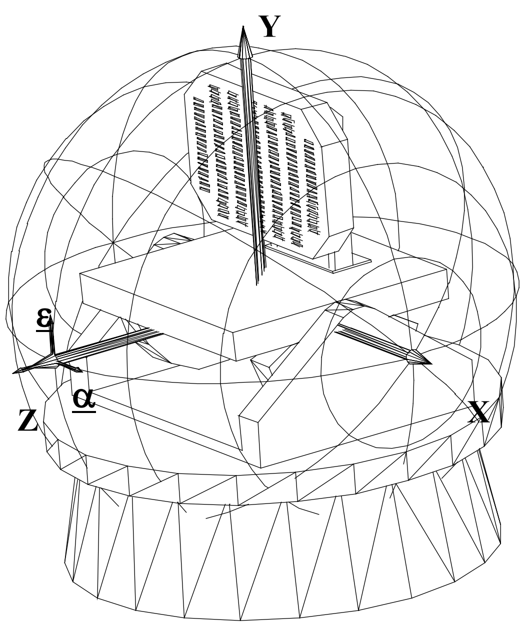

Figure 3 Elevation over azimuth coordinate system .

vector components are the α and ε components.

In most applications any coordinate system can be used to represent positions or directions relative to the antenna coordinates. There are some applications where a paticular set of coordinates or vector components must be used to obtain correct results. One such application will now be described.

2. Combining Results from Different Antenna Orientations

A measurement application that illustrates when the proper choice of both the vector components and the coordinate system must be used to define directions has recently been developed at Nearfield Systems Inc. This application uses two or more planar near-field measurements on the same antenna where the antenna is rotated about one axis between each measurement. The results of these measurements can be used to extend the angular coverage of the planar near-field measurements or to estimate the magnitude of specific errors in a measurement. Both of these applications will be illustrated.

The angular coverage of planar near-field measurements is limited by the size of the scan plane, and the "region of validity" is defined by the angle between the edge of the AUT and the edge of the scan plane. In some applications, results are required over a larger angular region than is possible with the available scanner. The angular coverage can be increased by rotating the antenna and repeating the measurement. The results of the two measurements are then combined. Successful combination depends on using both the coordinate system and vector components that are appropriate for the antenna rotation.

In general for a single antenna orientation, any coordinate system such as (x, y, z); (k_x, k_y, k_z), (θ, ϕ); (α, ε); or (A, E); can be used with any vector components since the coordinate system defines a direction or location in space and the vector components define two orthogonal components of the electric field. In a sense the "natural" coordinate system is the one that corresponds to the vector components since the field vectors are along the lines of the corresponding coordinates. In the specific case of a rotated coordinate system, there is a compelling reason to use a specific coordinate system and a specific set of vector components as the "initial" or "natural" set. For rotation about the z-axis, θ, ϕ coordinates and vector components are the natural choice. For rotation about the x-axis, α, ε coordinates and vector components are the natural choice. For rotation about the y-axis, A, E coordinates and vector components are the natural choice. If these natural

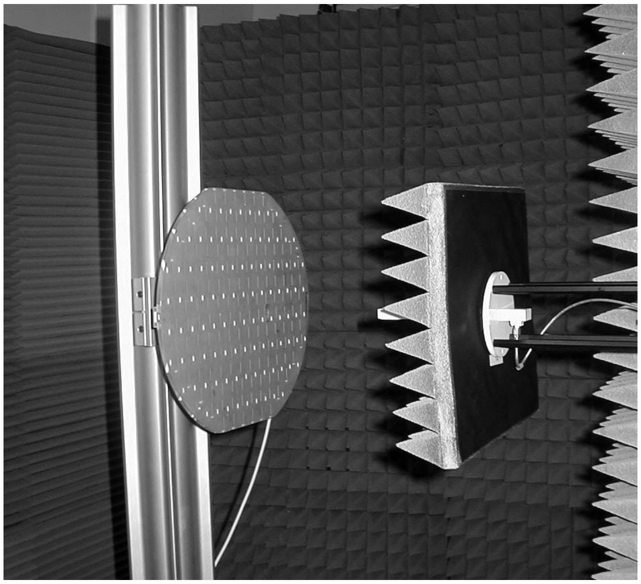

Figure 4 Slotted array test antenna in its initial un-rotated orientation.

coordinates and components are chosen there will not be any change in the shape of the pattern due to rotation, only a translation of the pattern. Once the translation has been taken care of, we can always convert to any other components or coordinates.

Figure 4 shows the antenna that was used for the following tests in its initial orientation with the main beam normal to the scan plane. It is an X-Band slotted array approximately 14 inches in diameter. With a planar near-field measurement length of 60 inches in x and y, and a z-distance of 8 inches, the resulting far-field pattern is valid over ±70 degrees in both azimuth and elevation. To increase the angular coverage in the azimuth direction, the antenna was rotated +20 degrees about the y-axis using a rotator that was aligned with its axis of rotation parallel to the y-axis of the scanner. This corresponds to the Azimuth angle of the coordinate system shown in Figure 2. Near-field measurements were repeated, for this antenna orientation and for a similar rotation of –20 degrees in Azimuth. Figure 5 shows the results of these three measurements along the horizontal principal plane. The +20 degree and –20 degree patterns have been shifted to put the peak on-axis for this display. The azimuthal coverage has now been increased to ± 90 degrees and it is apparent that the patterns show very good agreement within their common regions of validity.

These patterns have used AZ EL coordinates and vector components that are the natural choice for rotation about the y-axis. With this choice, the patterns should be shifted in Azimuth and the shape of the patterns should not change.

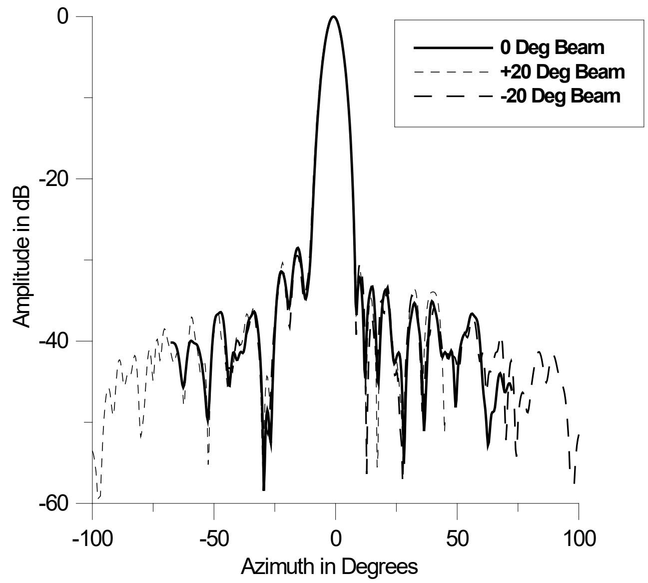

Figure 5 Angular coverage increased by combining steered beams.

This is illustrated in Figure 6 where vertical cuts through the peaks of the beams are plotted for the 0 degree, -20 degree and +20 degree antenna orientations. These patterns show excellent agreement, that is in contrast to Figure 7 which is

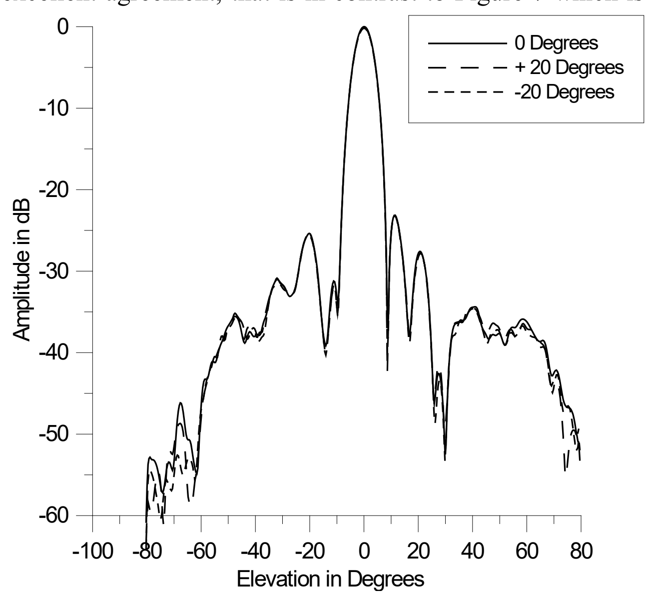

Figure 6 V-cuts through beam peak for three azimuth rotations of the antenna. Az EL coordinates and vector components used.

a similar comparison of the V-cuts using α-ε coordinates and components. The comparison here is especially poor at angles far off axis.

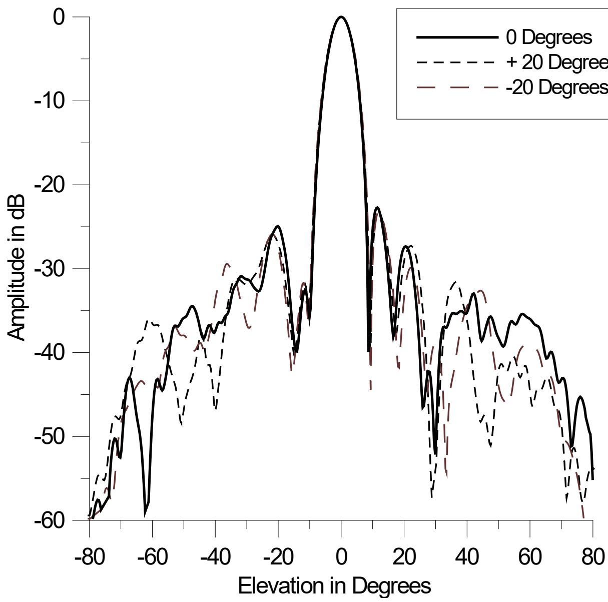

Figure 7 V-cuts through beam peak for three azimuth rotations of the AUT. Alpha Epsilon coordinates and vector components used.

The differences in the patterns in Figure 7 do not mean that there is an error in the measurement or that it is "incorrect" to use the α-ε coordinates and components. All three curves are a correct and valid representation of the field for the given situation. The patterns are different because the shape of the pattern changes when using these coordinates and components with a rotation about the y-axis. If the shifted patterns are going to be combined, or if the shifted patterns are going to be compared and the differences used to estimate errors in the measurement, A E coordinates and vector components must be used with a rotation about the y-axis.

3. Estimating Errors in Planar Near-Field Measurements

Comparing the results of two different near-field measurements can be an effective tool for estimating errors if the measurement system is changed in a known way between measurements[2]. The change in the measurement system is designed to change the sign of one or more sources of error while leaving other sources unchanged. Rotation of the antenna about one axis can identify some sources of error that are difficult to quantify with other tests as illustrated by the following examples.

If the correct coordinates and components are used for a given rotation, if the rotation is precisely known, and if there are no errors in the measurement system, the original

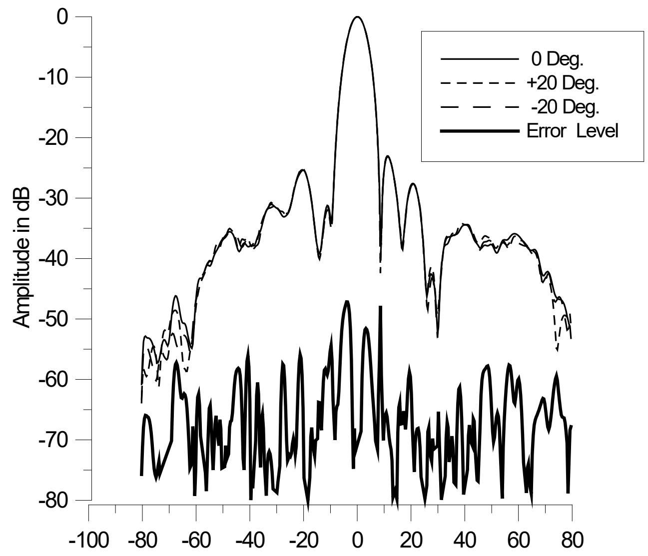

Figure 8 Using comparison of rotated patterns to estimate error levels.

and rotated patterns should agree exactly. For the azimuth rotations previously described, the rotations were carefully controlled and known, and the differences seen in Figure 6 are due to measurement errors. Multiple reflections between the AUT and the probe produce some errors in every near-field measurement. This error can be identified and partially corrected by taking measurements at a series of 4 z-distances in increments of $\lambda/8$. This was done for all three of the azimuth beam rotations and the four far-field measurement results for each beam rotation were averaged to reduce the effect of the multiple reflections. The average far-fields for the three beam rotations were then compared as shown in Figure 8 and a residual error signal calculated that would cause the differences in the patterns. In the main beam region, where the multiple reflection error is the largest, the residual error level is approximately –50 dB while in the sidelobe region it has been reduced to approximately –60 to –65 dB. The error sources that should be identified by the steering of the beam in Azimuth are X-position errors, phase linearity and room reflections in the Azimuth directions. From the results shown in Figure 8, the combined effect of these error sources is less than -60 dB below the main component peak.

4. Conclusions

Four different spherical coordinate systems and the associated vector components associated with these coordinates have been defined. Far-field or Near-field measurements can be presented using any of these systems, and each is a valid representation of the antenna pattern and polarization. If comparisons are made between different measurements or between measurements and theoretical calculations, the coordinates and components must agree. Also if the antenna is rotated about one axis and measurements are combined or compared, the proper coordinates and components must be used that will not change the shape of the pattern for the rotation.

References

[1] A. C. Newell, G. Hindman*, "Spherical coordinate systems for defining directions and polarization components in antenna measurements," Proceedings of the 20th Annual AMTA Meeting and Symposium, pp 113-116, Montreal, Canada, 1998.*

[2] A. C. Newell, "*Error Analysis Techniques for Planar Near-Field Measurements", IEEE Trans. Antennas Propag., Vol 36, No. 6, pp. 754-768, June 1988.*