Near Field Acquisition Simulation And Far Field Transformation

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Abstract—A near-field range consists of a microwave interferometer connected to a field probing antenna carried by a very precise robotic system. The probe antenna is moved throughout a planar, cylindrical, or spherical surface near the antenna under test (AUT).

In this paper near field and far field results are presented for a simulated antenna array using MATLAB. Uniform excitation has been used. The main focus of the paper is on how far field pattern can be calculated using FFT. The analysis gives a first cut insight to the final pattern of the array once the production has been done to the design engineers. Also the impact of failures of elements can be analyzed beforehand.

The antenna array considered here is a S-band planar array. The elements are arranged in a triangular grid with horizontal and vertical element to element separation as 1/2 mm (approx). Both Uniform and Taylor excitation of the elements have been considered. The near field data is sampled at a distance of 0.5 (approx) and at a probe to antenna separation of 5.

Keywords — near field range; far field; Taylor; FFT

I. INTRODUCTION

The near field measurement system operates by measuring the phase front of the AUT and then mathematically transforming the phase front into the equivalent far-field spectrum. The transform input and output are at the same location, the location at which the measurements were made. As the near field radiated energy components are always travelling in a straight line so the transformation results is equivalent of the farfield pattern. Three basic methods have been developed to transform a plane polar phase front into an equivalent far-field angular spectrum:

(i) Interpolation and FFT
(ii) Weighted FDFT and
(iii) Fourier/Jacobi Bessel Expansion

The most common and efficient method is the interpolation and FFT method.

II. COMPUTING FAR FIELD PATTERN

In a planar array the antenna elements are located on some type of regular grid in a plane. An example that would apply to a rectangular grid is shown in Figure 1. The array lies in the X-Y plane and the array normal, or boresight, is the Z-axis. The intersections of lines with the numbers by them are the locations of the various elements. The line located at the angles \( \theta \) and \( \phi \) points to the field point (the target on transmit or the source, which could also be the target, on receive). The field point is located at a range of \( r \) that is very large relative to the dimensions of the array (far field assumption).

Figure 1: Geometry of Planar Arrays

In the coordinate system of Figure 1 the field point is located at

\[
(x_f,y_f) = (r \sin \theta \cos \phi, r \sin \theta \sin \phi)
\] (1)
The 00 element is located at the origin and the \( mn \)th element is located at \((mdx, ndy)\) where \( dx \) is the spacing between elements in the \( x \) direction and \( dy \) is the spacing between elements in the \( y \) direction. With this and Equation 1 we can find the range from the \( mn \)th to the field point, \( r_{mn} \)

\[
rmn = \sqrt{(xf - mnx)^2 + (yf - ndy)^2} \tag{2}
\]

\[
rmn = r + mnx\sin\theta\cos\phi + ndy\sin\theta\sin\phi \tag{3}
\]

where \( r \) is much greater than the antenna dimension. The voltage received from \( mn \)th element at distance \( r \) is, therefore, given by

\[
V_{mn}(\theta, \phi) = V_{rmn}\exp\left(\frac{j2\pi}{\lambda}(mdx\sin\theta\cos\phi + ndy\sin\theta\sin\phi)\right) \tag{4}
\]

where \( amn \) is the weighting applied to the \( mn \)th element. Given that the outputs of all \( mn \) elements are summed to form the overall output, \( V(\theta, \phi) \), we get

\[
V(\theta, \phi) = \sum_{n=0}^{N} \sum_{m=0}^{M} V_{mn}(\theta, \phi) \tag{5}
\]

\[
V(\theta, \phi) = Vr\exp\left(\frac{j2\pi r}{\lambda}\right) \sum_{n=0}^{N} \sum_{m=0}^{M} amn\exp\left[-\frac{j2\pi}{\lambda}(mdx\sin\theta\cos\phi + ndy\sin\theta\sin\phi)\right] \tag{6}
\]

where \( M+1 \) is the number of elements in the \( x \) direction and \( N+1 \) is the number of elements in the \( y \) direction. If we divide by \( Vr \) and ignore the phase we can write

\[
A(\theta, \phi) = \sum_{n=0}^{N} \sum_{m=0}^{M} amn\exp\left[-\frac{j2\pi}{\lambda}(mdx\sin\theta\cos\phi + ndy\sin\theta\sin\phi)\right] \tag{7}
\]

If we put \( u = \sin\alpha = \sin\theta\cos\phi \) and \( v = \sin\beta = \sin\theta\sin\phi \) equation (7) becomes

\[
A(\sin\alpha, \sin\beta) = \sum_{n=0}^{N} \sum_{m=0}^{M} amn\exp\left[-\frac{j2\pi}{\lambda}(mdx\sin\alpha + ndy\sin\beta)\right] \tag{8}
\]

Or

\[
A(u, v) = \sum_{n=0}^{N} \sum_{m=0}^{M} amn\exp\left[-\frac{j2\pi}{\lambda}(mdx u + ndy v)\right] \tag{9}
\]

The \( A(u, v) \) in equation 9 has the form of a Fourier transform, albeit a two-dimensional Fourier transform. So we can use the 2-D FFT to compute \( A(u, v) \).

Before proceeding any further, few details on the type of grid that we have used (triangular) is worth mentioning. The most common element packing scheme besides rectangular packing is called hexagonal or triangular packing. Figure 2 contains sketches of sections of a planar array with rectangular and hexagonal (or triangular) packing. The dashed elements in the hexagonal packing illustration are dummy elements that must be included when one uses the 2-D FFT to compute the radiation pattern for an array with hexagonal packing. The need for the dummy elements stems from the fact that the FFT method must use rectangular packing. The amplitudes of the dummy elements are set to zero.

Following are the steps to be taken for near field to far field transformation:
1. Define the scan area and create an array of the sampling points in terms of \((x, y, z)\) location. The \( z \) distance in this case will remain a constant.
2. Define the Transmit/Receive aperture in terms of its \((x, y, z)\) location.
3. Get the \( rmn \) value for all elements for a particular sample point and add them to get the \( A(u, v) \) value at that point. A matrix is created for all the sample points in a similar way.
4. The matrix obtained above is the near field data. Then a 2-D Fourier transform of the measured phase front is performed, where the input is uniformly sampled phase front and the output is measured spatial frequency spectrum.
5. Interpolation is done if required which is done by using zero-padding Fourier Transform techniques. The last step is to convert the spatial frequency spectrum to an angular spectrum by mapping using a sine inverse function where \( \theta = \sin^{-1}(u) \) and \( \phi = \sin^{-1}(v) \).

III. RESULTS

We have taken 8X8 triangular array with \( \lambda/2 \) mm (approx) spacing between the elements. The azimuth and elevation plot of the array is given in figure 3 and 4. The Azimuth and Elevation beamwidth are 11.58 and 11.12 degree respectively. Similar results have been obtained using software PCAAD which is used for getting radiation pattern of antennas.

IV. CONCLUSION

The present work focuses on methods to obtain the radiation pattern of any planar array beforehand and at any desirable cut.

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