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# Noise reduction in far field pattern from cylindrical near field measurements

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***Abstract- Abstract***—The representation of the radiation pattern of an antenna from the near field values through the far field parameters is a most common approach done for all the geometrics. As the distance of the farfield is too long the parameters of farfield such as gain, directivity, side lobe level, beam width cannot be obtained directly from the farfield values. The main objective of this paper is to reduce the signal to noise ratio (SNR) in the far field pattern of cylindrical antennas. In order to reduce the noise two methods are proposed. They are the spatial filtering and modal filtering. The basic principle behind these two methods is the same. It is assumed that the Cylindrical near Field (CNF) parameters are affected by Gaussian noise and are transformed to Cylindrical Modal Coefficients (CNC) so that it is convenient to reduce the value of noise. The far field values are extracted from the near field values by use probe selection and probe correction and then the 3d view of the far field values are plotted on the basis of theta and rho which are shown in the numerical analysis.

***Index Terms***— Signal to Noise Ratio (SNR), Cylindrical near Field (CNF), Cylindrical Modal Coefficients (CNC), probe selection, probe correction.

## 1. INTRODUCTION

The measurement of the near field values which is the widely used techniques for the past decades. It is difficult to predict how the error on near field values will affect the far field values since the far field is obtained from the near field values.

It is not able to explicit the far field error in account with acceptable value so that there is a possibility of error or noise in the far field. The expressions for predicting the errors in the near field were not obtained for the cylindrical and spherical cases.

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The far field noise is a disputable process, for each accomplishment of new measurement is varied. Hence it is not easy to predict the far field values in terms of an acceptable data. The spatial filtering and modal filtering process specifies the solution for the calculation of the far field values. The error or the noise is removed or the value of error does exceed the specified probability. Thus the boundary for the error value gives a good power of extracting the effect of the errors in the far field pattern. In addition to this the paper shows the numerical analysis for the elevation in nonstationary nature and azimuthal process as colored. Thus, the far field signal to noise is ratio appears to be a simple value but it conceals a complicated marvel.

This paper is systematized as follows. In the section II the method for the determination of far field values from the near field values is derived. In Section III it is shown how the autocorrelation far field noise for the Gaussian near field value is derived. Section IV shows the simulated results of far field value in 3D plot, elevation angle and azimuthal values are given.

## 2. METHOD FOR THE DETERMINATION OF FAR FIELD VALUES FROM THE NEAR FIELD VALUES

A right circular cylinder of radius ‘r’ which is enclosing the cylindrical antenna, as shown in figure 1is considered. The near field values if an antenna are specified in terms of cylindrical coordinate system (r,ϕ,z) and the far field values of the cylindrical antenna is depicted in terms of spherical coordinates (R,θ,Φ).

When the tangential components of the cylindrical antenna are measured, the electric field radiated from the antenna is given as the superposition of the cylindrical waves.

$$E_z(\phi,z)=\sum_{n=-\infty}^{\infty}\int_{-\infty}^{\infty}[b_n(n)\frac{\Lambda^2}{k}H_n^{(2)}(\Lambda a)- \quad a_{n(h)})]e^{jn\phi}e^{-jnz}dh \qquad (1)$$

$$E_\phi(\phi,z)=\sum_{n=-\infty}^{\infty}\int_{-\infty}^{\infty}[b_n(n)\frac{\Lambda^2}{k}H_n^{(2)}(\Lambda a)- \quad a_{n(h)})]e^{jn\phi}e^{-jnz}dh \qquad (2)$$

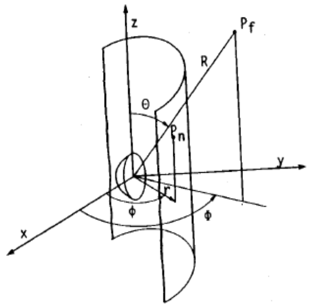


Figure 1 Geometry of Problem

where k is the value of the wave number and $H_n^{(2)}(\wedge a)$ is the Henkel function of second order value of n.

These coordinates of the cylindrical type is then transformed to the spherical type in the farfield region. When the value of arbitrary probe is used the same case of transformation is done. This forms the basic behind the near field to the far field transformation.

By using 2 dimensional Fast Fourier Transform (FFT) the tangential value of the electric field on the cylinder for the modal coefficients $a_n(h)$ and $b_n$(h) can be obtained easily.

The antenna farfield pattern can be effectively analyzed by using the electric field of the ɵ and φ values obtained in the Fourier transform. Since the modal coefficients are analysed by the discrete Fourier transform as it makes the aliasing errors negligible.

The spectral content can be given by

$$\Delta_z \leq \frac{\lambda}{2} \qquad ;\Delta_\phi \leq \frac{\Pi}{kp} = \frac{\lambda}{2p}.$$

where p is the radius of the sphere which is covering the antenna.

## 3. METHOD FOR THE DETERMINATION OF FAR FIELD AUTOCORRELATION

At this gesture, consider a complex white Gaussian noise with zero mean and $\sigma^2$ variance. The first step for the cylindrical near field to far field transformation is done by obtaining the CMC from the radiated electric field of the AUT. When the modal coefficients are calculated then it is used for computing the farfield of the AUT. There are two types of measurement which depends on the type of probe which is used to obtain the value of the modal expansion of the farfield of AUT. The choice of the probe depends on the orthogonality of the polarization.

Here, the far field noise due to the near field noise is found. This is done by considering that the near field has only noise and then the transformation is applied to that noisy data. The near field of the cylindrical surface is given by $n_{nf}(z_i,\phi,l)$ which is a Gaussian noise in nature. The grid is given by the points of sample as $z_i$ and $\phi_i$. The vertical spacing and azimuthal spacing are taken to be a constant.

For the case of vertical spacing the number of measurement is $N_z$ and then the azimuthal spacing it is given by $N_\phi$. The first and foremost step in this case of the near field to farfield transformation is to apply Fourier transform to the near field data. It has two variables in the transformed domain. The DFT of the of the near field data is given by

$$N_{nf}(k,n)= \left(\frac{\Delta z \Delta \phi}{2\pi}\right) \sum_i^{N_z} \sum_l^{N_\phi} n_{nf}(z_i,\phi_l) e^{jkzi} e^{-jn\phi l} \quad (3)$$

Next is to apply the autocorrelation of the DFT noise

$$R_N(p,q)=N_z N_\phi \sigma^2 \left(\frac{\Delta z \Delta \phi}{2\pi}\right) \delta(p,q) \quad (4)$$

The autocorrelation function is given for the white Gaussian noise since the psd (power spectral density) as per the DFT of the autocorrelation is flat in nature. The cylindrical modal coefficients (CMC) to the corresponding cylindrical near field noise waves are related to the Fourier transform. The far field components are obtained for the values of ɵ and ϕ. It is given by the real and imaginary values for the case of ɵ and ϕ. The mean and variance of the noise term depends on the probe cylindrical correction values that are the radiation pattern and hence the effect of noise wholly depends on the probe correction and the type of polarization.

When the radiation pattern with noise contamination is given by

$$\breve{E}(k,\phi) = \vec{E}(k,\phi) + \vec{n}(k,\phi) \quad (5)$$

where $\vec{n}(k,\phi)$ is the Gaussian noise with variance of $\sigma_{ff}^2$.

The farfield magnitude for the polarization is given by

$$\left(\vec{E}\right) = \lfloor R(E+n) \rfloor + j \lfloor I(E+n) \rfloor$$

$$=(X^2+Y^2)^{1/2} \quad (6)$$

Where X and Y are the real and imaginary part of E+n with mean of R(E) and I(E).

$$\sigma_{re}^2=\sigma_{im}^2=1/2\sigma_{ff}^2 \quad (7)$$

The farfield noise of the perturbed nature is a function of farfield variance and unperturbed farfield noise. So the unperturbed value is obtained from the contaminated near field noise. The near field noise can be obtained iff only prior knowledge of the radiation pattern of the AUT is available. The farfield signal to noise ratio is defined as

$$[S/N]_{FF}=(E_{FF}^{MAX})^2/ \sigma_{ff}^2 \quad (8)$$

Where $E_{FF}^{MAX}$ is the maximum value of the electric field in the transformed farfield .

$\sigma_{ff}^2$ is the variance of the farfield .

## 4.PERFORMANCE MEASURE FOR THE TRANSFORMED FARFIELD

SNR:

The most popular metric used to give the quality of a signal is the signal to noise ratio. The ratio of signal power to the noise power is known as signal to noise ratio. SNR can be expressed in decibels. It can be given by

$$SNR(db) = 10 \log_{10} \frac{\sigma_x^2}{MSE} \quad (9)$$

PSNR:

Peak value of SNR is the most common case of denoting the input signal. Peak signal to noise ratio is given by the ratio of maximum value of the signal power to the maximum of the noise corrupted signal. It is given in decibels by

$$PSNR(db) = 10 \log_{10} \frac{255^2}{MSE} \quad (10)$$

where the value 255 is the peak in image signal.

MSE:

The measure of the average value of the square of the estimator output to square of the estimated output. It is also known as the rate of distortion. It can also given in terms of decibel as

$$MSE(db) = \frac{1}{xy} \sum_{m=0}^{x-1} \sum_{n=0}^{y-1} X(m,n) - Y(m,n)^2 \quad (11)$$

## 5.RESULTS AND DISCUSSION

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For the values of certain frequency, cylindrical length, and then the radius the near field to the farfield transformation is to be found. It is done in the matlab by using the GUI. Figure 2 shows the loading of the input.

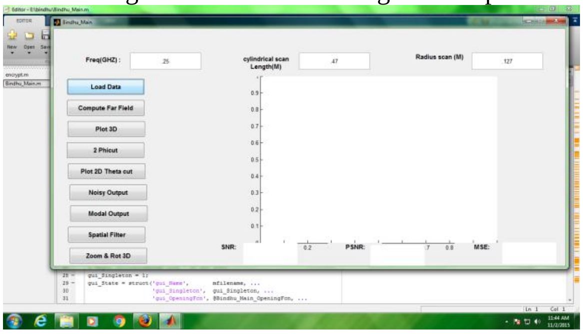

Figure 2 loading of the input

Figure 3 shows the farfield transformation from the near field values

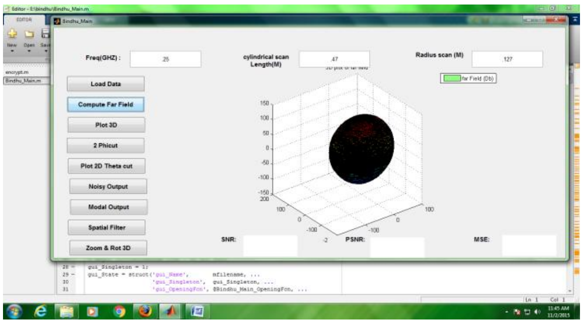

Figure 3 computation of the farfield pattern

Figure 4 shows the farfield in the 3 dimensional plots. It has the 3 planes to represent the phi ,rho ,and the radius values respectively.

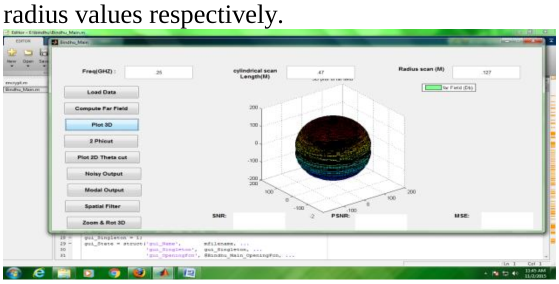

Figure 4 Farfield in 3d

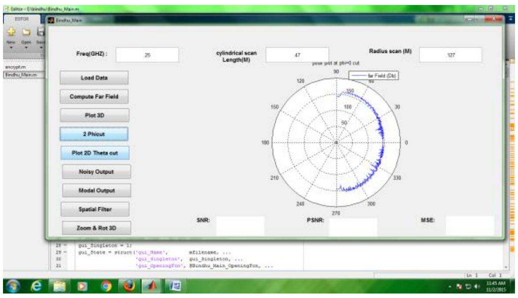

Figure 5 Phi Cut

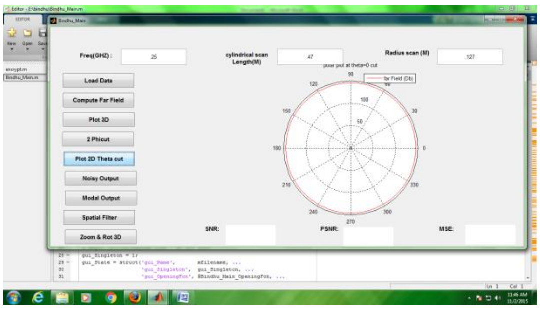

Figure 6 Theta Cut

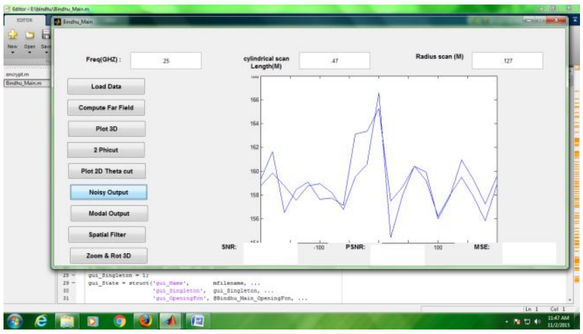

Figure 7 Noisy Output

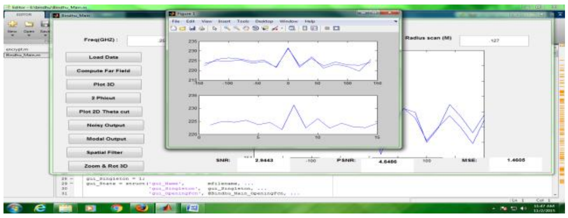

Figure 8 Modal Filtering Output

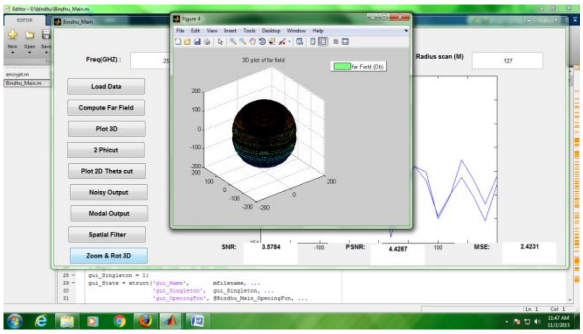

Figure 9 zooming and rotating

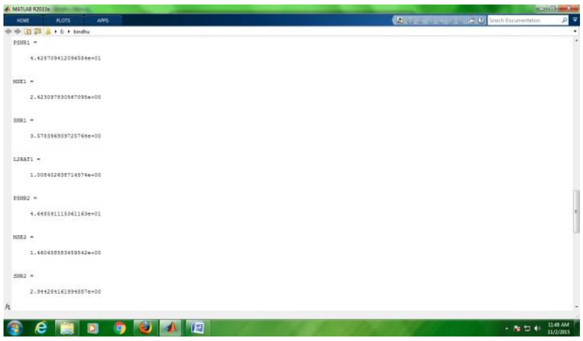

Figure 10performance metrics for both filtering

CONCLUSION

The expression for the far field from the auto correlation which is obtained from the near field data is derived. The farfield transformation from the near field random noise is obtained. Further, it also shows the two types of filtering methods states the filtering of the signal to noise ratio from the near field values. Thus by filtering the field values from the near field pattern the noise value was dramatically reduced. The two methods to reduce the far field noise values from the cylindrical measurements were given. In the modal filtering the probe correction is done and the factor used for oversampling increases the SNR value. It is independent of the shape of the antenna and it can be used for other arbitrary geometries. The spatial filtering uses the plane wave spectrum (PWS) technique which is used to give the extreme farfield values. It gives better value than the modal filtering since the spatial filtering has some prior knowledge of the antenna under test (AUT) but it depends on the position where the antenna is placed and the size of the antenna. The effectiveness of the two methods were given by the numerical results and the reduction in the signal to noise ratio (SNR) is also obtained.

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