Non-Linear Optimization of the Excitation Coefficients of an Array Antenna of a Large-number Elements to reduce the Amplitude Ripples in the mm-Wave Hotspot Area Illumination

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Abstract **– A 60GHz compact-range communication system is designed for coverage to 30cm width and 10m distance by an uniformly excited array antenna of a 64x64-element array antenna. The experiments showed that BER decays in non-far region which could come due to the ripple of the field. In this paper, we obtain new excitation coefficients to reduce the ripples thoroughly by using non-linear optimization.**

Index Terms **— array antenna, near region, ripple, optimization.**

1. Introduction

A 60GHz compact-range communication system that uses an array antenna of a large-number elements in order to make wide and long coverage has been proposed [1]. However, the array antenna is uniformly excited so that the ripples of the field are observed as shown in Fig.1 and Fig.2 and may deteriorates BER. The excitation coefficients of the array antenna which reduces the ripples of the field in the non-far region along the *z*-axis is designed by using non-linear optimization.

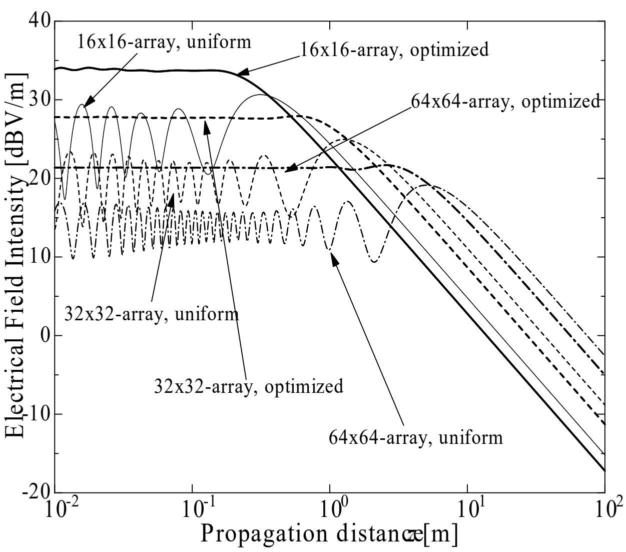

Fig. 1. Electrical field along the *z*-axis by uniform arrays

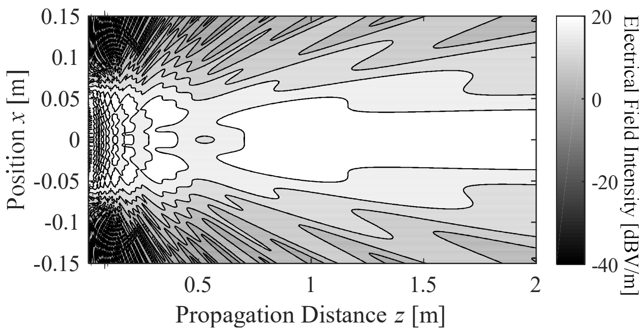

Fig. 2. Electrical field in the *xz*-plane by the uniform 32x32-array

2. Antenna Model

We consider that the antenna element is a waveguide slot and each slot is replaced to an infinitesimal magnetic dipole in order to calculate the electrical field as shown in Fig.3. When the array arrangement is an N-by-N square array, the excitation coefficient is expressed as $\boldsymbol{a}\boldsymbol{a}^T$ using a vector $\boldsymbol{a}$ (size: N) that follows $\boldsymbol{a}(N - n + 1) = \boldsymbol{a}(n)$. In this equation, T means transposition of a matrix.

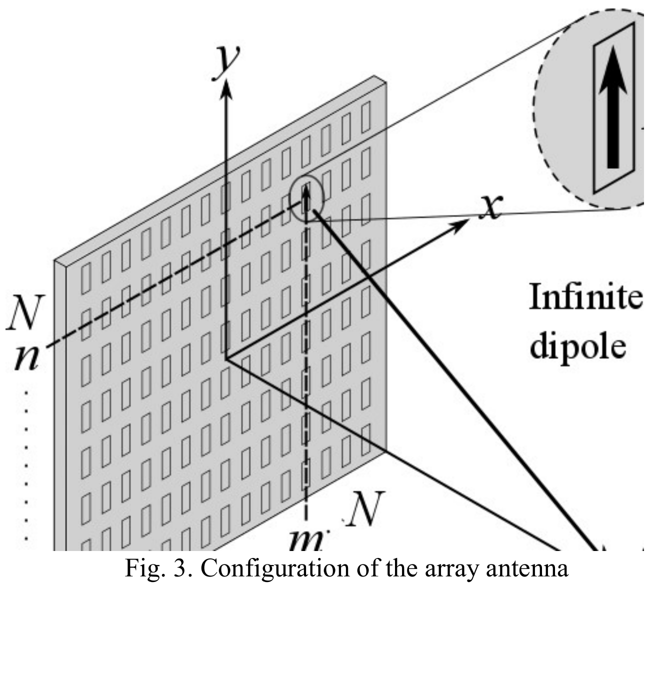

Fig. 3. Configuration of the array antenna

3. Optimization

The optimization problem in order to reduce the ripples of the field in the non-far region of the array antenna is expressed as below.

$$\underset{\boldsymbol{a}\in[0,1]^N}{\text{minimize}}\, f(\boldsymbol{a}) = \int_{U_{z\,\min}}^{U_{z\,\max}} \left| \frac{\partial E_{\text{dB}}(u_z, \boldsymbol{a})}{\partial u_z} \right| du_z$$

$E_{\text{dB}} = 20\log_{10}|\boldsymbol{E}|$, $u_z = \log_{10} z$, $U_{z\,\max} = \log_{10}Z_{\max}$, $U_{z\,\min} = \log_{10}Z_{\min}$ and the z-axis is oriented perpendicularly to the antenna as shown in Fig.3. The evaluation function $f(\boldsymbol{a})$ means the integration of the absolute of the slope of the electrical field intensity in log-log scale. When $f(\boldsymbol{a})$ decreases, the ripple of the electrical field decreases. The optimization is based on the interior-point method [2].

The conditions in the optimization are listed in Table I.

TABLE I
Conditions in the calculation and the optimization

Array position	Rectangular plane
Number of elements	16x16, 32x32, 64x64
Model of the element	Infinitesimal dipole
Frequency	61.5GHz
Spacing of the elements	$0.86\lambda_0 = 0.42$ mm
[$Z_{\min}$, $Z_{\max}$]	[0.01 m, 100 m]

4. Simulation Result

(1) Excitation coefficients

The optimized excitation coefficients normalized by a radiation power are given in Fig. 4 and Fig.4.2. The coefficient distributions have been shaped by tapers. The interference by the excitations around the edges of the array antenna is suppressed.

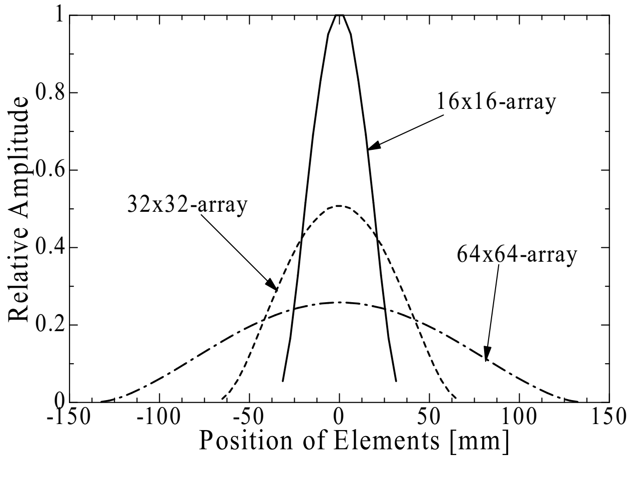

Fig. 4. Optimized excitation coefficients along the x-axis

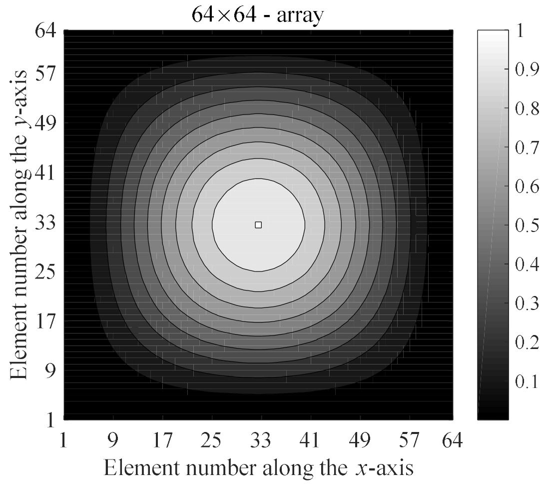

Fig. 5. Optimized excitation coefficients in the xy-plane

(2) Electrical field intensity by the optimized arrays

The electrical field intensity by the optimized coefficients is given in Fig.1.1 and Fig.4.3. The ripples in the non-far region are reduced when the excitation coefficient is optimized. On the other hand, the effective aperture area of the antenna becomes smaller and the directivity decreases by 3dB in the far region in comparison with the uniform array.

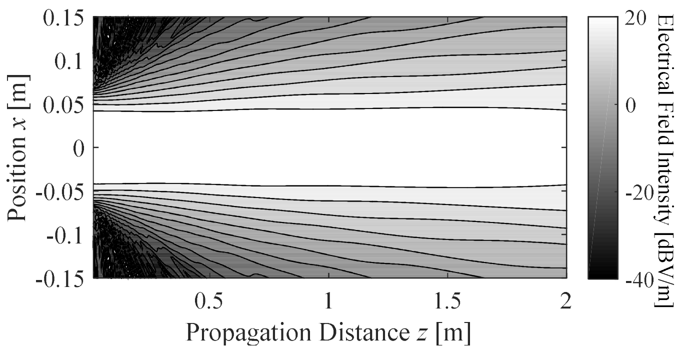

Fig. 6. Electrical field in the xz-plane
by the optimized 32x32-array

5. Conclusion

We have obtained the excitation coefficients of the array antenna if a large-number of elements which almost completely reduces the ripples of the field in the non-far region by using non-linear optimization.

References

[1] M. Zhang, et al., *IEEE Trans. Antennas Propag.*, vol. 65, no. 8, pp. 3432-3440, Aug. 2015.

[2] Byrd, et al., *SIAM Journal on Optimization*, vol. 9, no. 4, pp. 877-900, 1999.