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Characterization of Dipole Array Antenna Using Generalized-Scattering Matrix and Spherical Mode Analysis

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Abstract A method for characterizing dipole array antenna is presented in this paper using generalized scattering matrix (GSM) analysis and spherical mode analysis. The proposed method provides the coupling characteristics between elements such as active field pattern and active input impedance of a given dipole array. The method only needs the isolated antenna element parameters that are obtained by simulation tool, FEKO. The overall GSM of the given dipole array antenna is calculated with the isolated antenna element parameters and addition theorem of spherical mode analysis. The result is confirmed by simulation of the whole array structure.

Keyword Dipole antenna array, Massive MIMO, Mutual coupling, General scattering matrix, Spherical mode analysis

1. Introduction

It is well known that the mutual coupling between antennas affects the antenna performance, in general, in a negative way.**[1]** Recently, as array antenna closely spaced with a number of elements, like Multiple Input Multiple Output (MIMO) antenna, has been commonly used, the analysis of mutual coupling between antenna elements has been researched.**[2]** And there are some researches verifying how the mutual coupling is reduced. [3], [4]

In this paper, the algorithm with GSM and spherical mode analysis is proposed. It is designed for examining the characteristics of any arbitrary size of square lattice dipole array antenna with mutual coupling effects. The results are verified by compared with that of FEKO.

2. Theory

GSM of each antenna in an array can be described as follows, where $b^i_s = b_i - a_i$ and I_i is the identity matrix. [5]

$$\begin{bmatrix} w_i \\ b_i^s \end{bmatrix} = \begin{bmatrix} \rho_i & r_i \\ t_i & s_i - I_i \end{bmatrix} \begin{bmatrix} v_i \\ a_i \end{bmatrix} \qquad (1)$$

And using the addition theorem of spherical mode analysis, each antenna parameters are translated to another antenna. As a result, as derived in [6], the overall GSM can be obtained as (2), and each matrix are obtained by (3)

$$\begin{bmatrix} w \\ b^s \end{bmatrix} = \begin{bmatrix} \Gamma_G & R_G \\ T_G & (S_G - I_G) \end{bmatrix} \begin{bmatrix} v_i \\ a_i \end{bmatrix} \qquad (2)$$

$$\Gamma_G = \Gamma + RG[I - (S - I)G]^{-1}T$$
$$R_G = R + RG[I - (S - I)G]^{-1}(S - I)$$
$$T_G = [I - (S - I)G]^{-1}T$$
$$(S_G - I_G) = R + RG[I - (S - I)G]^{-1}(S - I) \qquad (3)$$

In this way, while the whole array antenna is analyzed, the antenna element is evaluated just once unlike MoM simulation tools.

3. Design

The algorithm is made for examining the characteristic of an arbitrary square lattice dipole antenna array. As an example, 3x4 dipole array antenna is verified. The operating frequency is 1.5GHz. The material of dipole antennas is PEC. The length of dipole antennas is 8cm which is 0.4λ and the wire radius is 0.5mm. The both distances between elements in the x and y directions are 10cm which is 0.5λ. The port impedances are 50Ω. At the beginning, the GSM of dipole antenna element is obtained from the FEKO. The input voltages are applied as the table 1 for examining the active impedance.

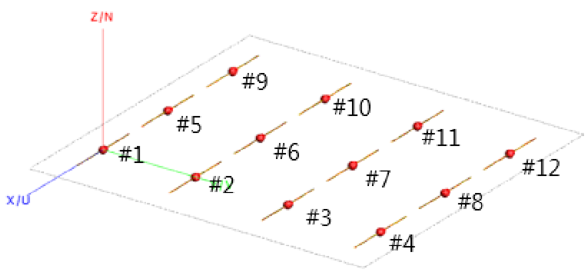


Fig. 1. The design of 3x4 dipole array antenna

	$Re(V_s)$	$Im(V_s)$		$Re(V_s)$	$Im(V_s)$
#1	11.314	-3.721	#7	11.582	-3.619

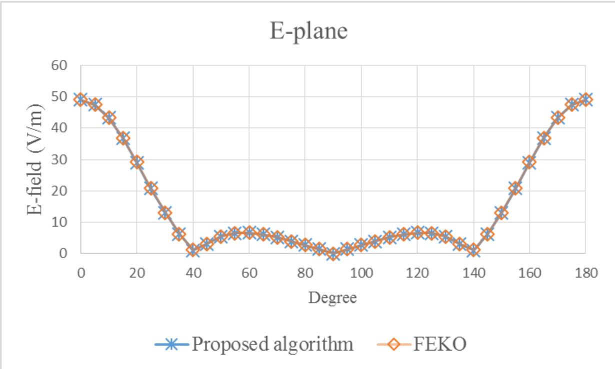
#2	11.589	-3.852	#8	11.311	-3.217
#3	11.589	-3.852	#9	11.314	-3.721
#4	11.314	-3.721	#10	11.589	-3.852
#5	11.311	-3.217	#11	11.589	-3.852
#6	11.582	-3.619	#12	11.314	-3.721

Table. 1. The input voltages

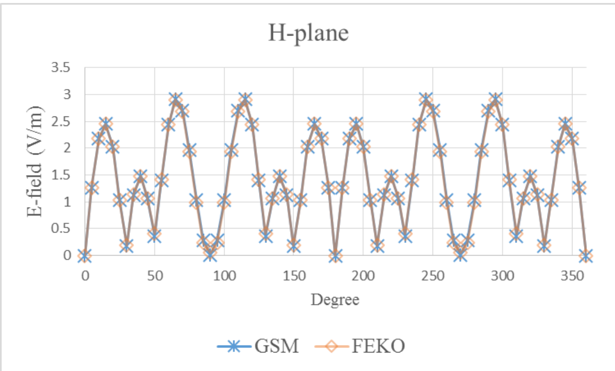
4. Result

A. Radiation pattern

The radiation pattern shown in Fig. 2. is obtained by the multiplication of T_G and wave functions for each spherical mode. When we compare the result with FEKO, the difference is extremely small.



(a)



(b)

Fig. 2. Radiation pattern of 3x4 dipole array antenna by proposed algorithm and FEKO. (a) E-plane. (b) H-plane.

B. Active impedance

The impedance of a single dipole antenna element is 47.984-35.071iΩ. By the mutual coupling between antennas, impedances of each antenna are changed from single antenna impedance, which is active impedance. As shown in Fig. 3., proposed algorithm gives proper results in the aspect of active impedance when compared with that of FEKO.

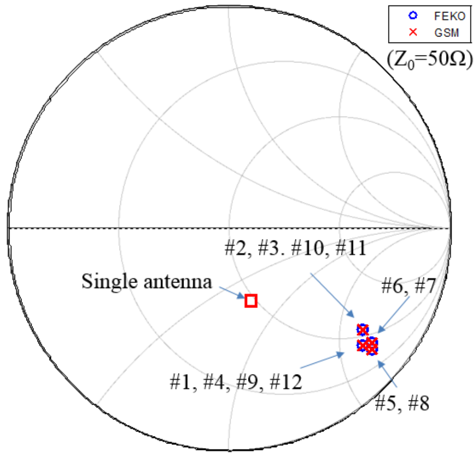


Fig. 3. Active impedance

5. Conclusion

The mutual coupling which modifies the characteristics of array antenna such as pattern and impedance can be analyzed using Generalized-Scattering Matrix and Spherical Mode Analysis. Since the proposed method needs only the antenna parameters of single, isolated antenna element used in the array, it can be useful to analyze the array antenna with complex geometrical structure.

6. Acknowledgment

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