Near-field Correlation in MIMO Antennas: A Necessary Revisit

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Traditionally, correlation coefficients calculated based on far-field radiation patterns as well as antenna currents through cross-correlation Green's functions, are utilized to characterize MIMO (multiple-input multiple-output) antennas [1]-[2]. However, modern day wireless networks (5G and beyond) often involve transceiver nodes interacting in the radiating as well as reactive near-field (NF) regions, eg. massive MIMO indoor base-stations communicating with nearby users. Therefore, wireless system designers require new performance metrics to characterize such NF MIMO communication channels [3]. With this objective, we define the near-zone electric and magnetic field correlation coefficients ρ_{12}^e and ρ_{12}^h in uniform propagation environment as [3]:

$$\rho_{12}^e = \frac{\int_{4\pi} (\mathbf{E}_1 \cdot \mathbf{E}_2^*)\, d\Omega}{\sqrt{\int_{4\pi} (\mathbf{E}_1 \cdot \mathbf{E}_1^*)\, d\Omega}\sqrt{\int_{4\pi} (\mathbf{E}_2 \cdot \mathbf{E}_2^*)\, d\Omega}} \text{ and } \rho_{12}^h = \frac{\int_{4\pi} (\mathbf{H}_1 \cdot \mathbf{H}_2^*)\, d\Omega}{\sqrt{\int_{4\pi} (\mathbf{H}_1 \cdot \mathbf{H}_1^*)\, d\Omega}\sqrt{\int_{4\pi} (\mathbf{H}_2 \cdot \mathbf{H}_2^*)\, d\Omega}}, \quad (1)$$

Here $\mathbf{E}_i$ and $\mathbf{H}_i$ ($i = 1, 2$ being the excited port-index) are respectively the near-zone electric and magnetic fields computed on a correlation sphere of radius r_c circumscribing the two-port system, and the integration of any pattern function F over the entire solid angle is given by $\int_{4\pi} F(\Omega) d\Omega = \int_0^{\pi} \int_0^{2\pi} F(\theta, \phi) \sin\theta d\theta d\phi$.

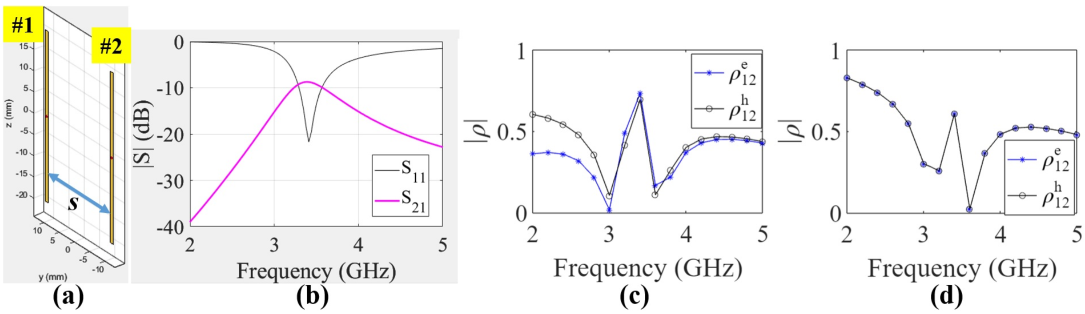

Figure 1. (a) Two-port system of thin-wire dipoles with individual length 0.47λ and $s = 0.25\lambda$, where λ is the free-space wavelength at 3.5 GHz. (b) Corresponding frequency variation of S-parameter magnitude. Computed values of $|\rho|$ for: (c) $r_c = 0.35\lambda$, (d) $r_c = 10\lambda$, where r_c is the radius of NF correlation sphere with center at origin.

Fig. 1 shows a two-port system of resonant thin-wire dipoles, operating in the sub-6 GHz 5G band around 3.5 GHz, simulated using MoM-based MATLAB Antenna Toolbox. We first obtain the **E** and **H** fields on a correlation sphere of radius r_c surrounding the two-port system, and compute ρ_{12}^e and ρ_{12}^h using (1). Clearly, as r_c is reduced (see Fig. 1(c)), we observe $\rho_{12}^e \neq \rho_{12}^h$ due to the non-TEM nature of the near-zone EM fields. However, as r_c is increased, both ρ_{12}^e and ρ_{12}^h become equal, and gradually converge to the far-field radiation pattern based correlation coefficient values (see Fig. 1(d)). Future extended work will focus on the near-zone electric and magnetic field correlation coefficients for multi-port arrays of larger aperture and elements other than simple thin-wire dipoles.

References

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