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Editorial

Mutual Coupling in Antenna Arrays

Hon Tat Hui,[1] Marek E. Bialkowski,[2] and Hoi Shun Lui[3]

[1] *Department of Electrical and Computer Engineering, National University of Singapore, 4 Engineering Drive 3, Singapore 117576*
[2] *School of Information Technology and Electrical Engineering, University of Queensland, St Lucia, Brisbane, Qld 4072, Australia*
[3] *Department of Signals and Systems, Chalmers University of Technology, 41296 Gothenburg, Sweden*

Correspondence should be addressed to Hon Tat Hui, elehht@nus.edu.sg

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Mutual coupling is an electromagnetic phenomenon which exists in many antenna arrays. In most of the usual cases it is detrimental to the antenna operation, although there are some examples in which its presence can be beneficial. Because of its varying impact, it has attracted a large volume of research to study its causes and remedies. The effect of mutual coupling on array antennas stretches over many different areas from the conventional use of antennas to their modern employment in such exotic areas as multiple-input multiple-output (MIMO) systems, diversity systems, medical imaging, and sonar and radar systems. Over the past years, there have been many methods proposed to study the mutual coupling problem and many solutions have also been provided. The development of ever-decreasing size radio transceivers has favored the emergence of small-size antenna arrays in recent years. Such new demands place the study of mutual coupling problem in an even more important priority.

This special issue provides for the first time an international forum for researchers in antenna mutual coupling research to disseminate their results and ideas. Nine dedicated papers from eight groups of authors have contributed to this special issue. To help interested readers to have a quick reference to the main themes of these papers, we briefly introduce them below.

The first paper "*An open-source code for the calculation of the effects of mutual coupling in arrays of wires and for the ASM-MBF method*" by C. Craeye et al. introduces a method known as "array scanning method-maro basis function (ASM-MBF)" to illustrate the fast numerical calculation and analysis of wire antenna arrays. Open-source codes in the Matlab language for both finite and infinite arrays are described and their use is demonstrated in suitably tailored examples. This work provides an easy-to-use tool for the general understanding of the mutual coupling phenomenon in antenna arrays.

In the second paper "*Mutual coupling compensation for direction-of-arrival estimations using the receiving-mutual-impedance method*" by H. S. Lui and H. T. Hui, the authors introduce a new idea in mutual coupling analysis by proposing a so-called receiving mutual impedance method (RMIM). This method, which is suggested to be specifically used with receiving antenna arrays, provides an accurate method for the analysis of the mutual coupling effect in receiving antenna arrays. A new concept of receiving mutual impedance is introduced and its significance and impact on mutual coupling analysis is fully explained and demonstrated. The receiving mutual impedance, which is fundamentally different from the traditionally defined mutual impedance (based on the open-circuit voltage concept) is used in a direction-of-arrival (DOA) estimation problem to yield accurate DOA estimation results. Interested readers are strongly suggested to find out more details from this paper.

The third paper, entitled "*Bandwidth enhancement of antenna arrays utilizing mutual coupling between antenna elements*" by M. Wang and W. Wu et al. introduces an interesting idea in mutual coupling analysis by relating the enhancement of an array's bandwidth to a proper manipulation of its input S parameters. The authors present a formula relating the VSWR bandwidth with the so-called frequency derivatives of the reflection coefficients, which in turn can be expressed in terms of the frequency derivatives of the S parameters. They further point out that a mutual cancellation of some of the S parameters can increase the bandwidth of an antenna array.

In the fourth paper, "*Decoupling of multi-frequency dipole antenna arrays for microwave imaging applications*," the authors E. Saenz and K. Guven et al. make use of a metasurface superstrate to reduce mutual coupling of a printed dipoles array. The metasurface consists of three layers of printed metallic strips aiming to spread the radiated field over a larger aperture, thus enhancing the final gain of the dipole array laid on top of it. It is found that this metasurface structure can reduce the mutual coupling by 3 dB to 20 dB, increase the boresight radiation, and reduce the endfire radiation.

In the fifth paper, "*Compact printed arrays with embedded coupling mitigation for energy-efficient wireless sensor networking*," C. G. Kakoyiannis and P. Constantinou use photonic bandgap (PBG) structures to reduce mutual coupling between compact printed antenna arrays used for the construction of wireless sensor networks. Their study shows that an efficient reduction of mutual coupling effect by 15–20 dB can be achieved by a proper design of the PBG structure. Furthermore, they show that impedance bandwidth can be maintained even with a substantial decrease in element separation.

The remaining four papers all deal with the antenna mutual coupling effect in MIMO systems. In the sixth paper of "*Optimization of training signal transmission for estimating MIMO channel under antenna mutual coupling conditions,*" X. Liu and M. E. Bialkowski investigate the effect of antenna mutual coupling on the performance of training-based channel estimation for MIMO systems. Two training-based channel estimation methods are intensively studied: the scaled least square (SLS) method and the minimum mean square error (MMSE) method. They find that the accuracy of MIMO channel estimation is governed by the sum of eigenvalues of the channel correlation matrix which, in turn, is affected by the mutual coupling in the transmitting and receiving antennas. A water-filling-based procedure is proposed to optimize the training signal transmission to minimize the MIMO channel estimation errors.

In the seventh paper of "*Effect of antenna mutual coupling on MIMO channel estimation and capacity*," X. Liu and M. E. Bialkowski further consider the antenna mutual coupling effect on MIMO channel capacity with imperfect channel estimations, that is, the case of lacking perfect channel state information (CSI). Their study investigates the effect of different antenna element separations on channel estimations and the resulting MIMO channel capacities.

The eighth paper, entitled "*The effect of mutual coupling on an HAP diversity system using compact antenna arrays*" by T. Hult and A. Mohammed, investigates the effect of antenna mutual coupling on MIMO system performance in a special diversity system. This system is the high altitude platform (HAP) diversity system proposed in Europe. In this HAP system, signal repeaters equipped with multiple antennas are deployed in the stratosphere layer to relay signals within a given local area, forming an effective MIMO communication system. The effect of mutual coupling which is present in the MIMO compact antenna arrays on the system capacity is rigorously studied, leading to determination of the optimal angle separations between transmitters and receivers that maximize the total mutual information of the HAP system. In this paper, a novel communication system is considered employing multiple antenna channels.

In the final ninth paper which entitled "*Mutual coupling effects on pattern diversity antennas for MIMO femtocells*," the authors Y. Gao and S. Wang et al. characterize the effect of mutual coupling on the performance of a diversity antenna system operating in MIMO femtocells. This is accomplished through experimental investigations. A suitable patch antenna is designed with two excitation ports to achieve pattern diversity. The dependence of the channel capacity on mutual coupling between the excitation ports is determined by measurements. This is an application study with practical measurement values provided.

All papers appearing in this special issue have been subject to a strict peer reviewing process. They are of high quality and address the mutual coupling problem from different angles and application perspectives. It is our expectation that through this special issue, some valuable ideas and conclusions on mutual coupling research are provided and at the same time, we hope that more ideas and research can be encouraged to come out in the future.

Hon Tat Hui
Marek E. Bialkowski
Hoi Shun Lui