Case study of the electromagnetic degrees of freedom in multi-antennas communications systems using FDTD

Man-Fai Wong*, Azeddine Gati, and Joe Wiart
Orange Labs, R&D, Issy Moulineaux, France
*Corresponding author e-mail: manfai.wong@orange-ftgroup.com

INTRODUCTION

In wireless communications, one way to gain further capacity or throughput is to use the spatial dimension of the channel through multi-antennas systems. Multiple Input Multiple Output (MIMO) is an area of active research since the first development by Forshini [1]. Instead of suffering from the impairments of the propagation channel, i.e. fading, multipath due to a complex environment, MIMO can on the contrary take advantage of the multiple scattering environments to increase the performance of the system. It is then interesting to analyze it from an electromagnetic perspective to gain insight from the physics and to determine the limits of the channel capacity.

MATERIALS AND METHODS

Loyka [2] has interestingly analyzed the capacity jointly by information theory and the laws of electromagnetics. Specifically, the modal expansion technique is used in overmoded waveguides or cavities to find the modes or the degrees of freedom of the channel over which the information is conveyed independently. However the antennas are ideally considered such that the calculations remain analytical. In this paper, we propose to use FDTD (Finite Difference Time Domain). It allows to model more realistically the antennas, their mutual coupling and the excitations of the modes inside the waveguide. The case study is sketched in Figure 1. Five propagating modes exist in this waveguide

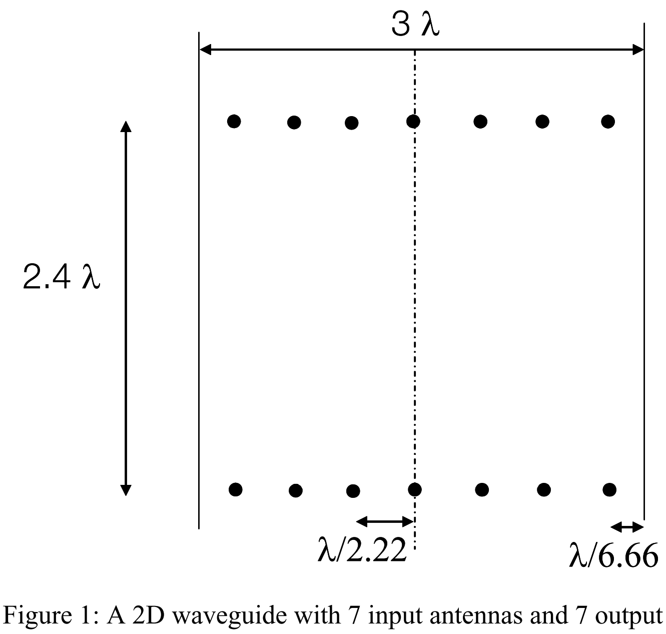

Figure 1: A 2D waveguide with 7 input antennas and 7 output antennas

RESULTS

The 14 antennas are considered as ports and the S-parameters for these ports are computed. Then the transmission channel is SVD decomposed and the singular values and eigenvectors are obtained. Five significant singular values are obtained and the eigenvectors can be plotted. For example in Figure 2, we can recognize the propagation of the dominant mode but it corresponds to the fifth ordered singular value meaning a better transmission is achieved through other higher modes. Another important point is that the distance between the two arrays is rather close. To emphasize this point, the metallic walls are removed, thus giving two close antenna arrays. This time, the number of significant singular values is 4, meaning that with this antenna configuration, 4 independent channels could be used. Figure 3 shows the eigenvector corresponding to the first singular value which looks like a single dipole propagation. To go further, the case when the 2 arrays in free space are far is simulated, and as expected only 1 mode is propagating. The eigenvector shows a beamforming mode maximizing the energy transfer.

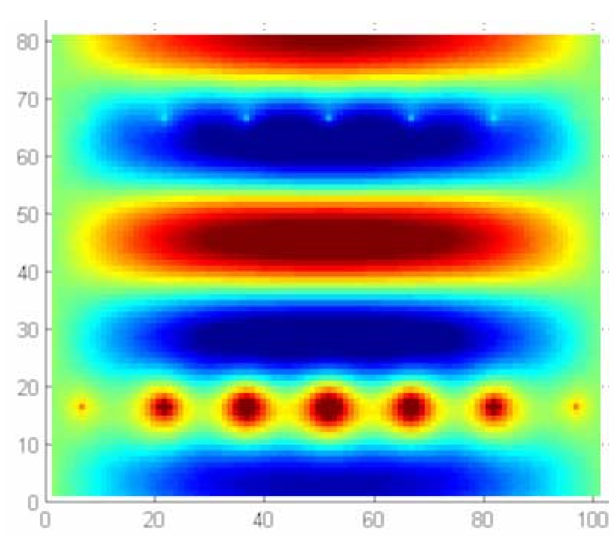

Figure 2: the eigenvector corresponding to the fifth most important singular value for the waveguide

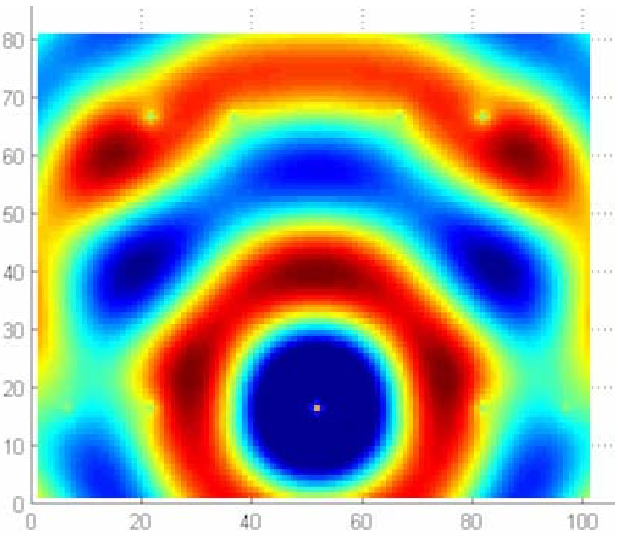

Figure 3: the eigenvector corresponding to the first singular value in free space

CONCLUSIONS

These case studies are very insightful to relate the MIMO system view to the electromagnetics in complex media. The authors believe that it is helpful to explore the physics based limits of MIMO systems.

REFERENCES

[1] G. J. Foschini. Layered space-time archictecture for wireless communciation in a fading environment when using multi-element antennas. *Bell Labs Tech. J.*, vol(1): 41-59, 1996.

[2] S. Loyka. Multiantenna capacities of waveguide and cavity channels. *Vehicular Technology, IEEE Transactions on*, vol(54): 863-872, 2005.