

# SMART ANTENNAS

*Tapan K Sarkar*

Syracuse University, Syracuse, New York

Phone: 315-443-3775, Fax: 315-443-4441

[tk Sarkar@mailbox.syr.edu](mailto:tk Sarkar@mailbox.syr.edu); <http://web.syr.edu/~tk Sarkar>

*Magdalena Salazar-Palma*

Universidad Carlos III de Madrid, Madrid, Spain

[m.salazar-palma@ieee.org](mailto:m.salazar-palma@ieee.org)

**SUMMARY:** There have been a large number of papers appearing in the scientific literature which claims that the antenna theory need to go through a revolution and new antenna theory of the future has tremendous potential under the guise of MIMO and smart antennas which is going to revolutionize electromagnetic theory and communication systems and so on. However, this is rather surprising as Maxwell's equations are one of the few equations of mathematical physics that has not gone through any changes since Hertz put them in the appropriate scalar form and Heaviside in the vector form over one hundred and twenty five years ago. This is one of the rare theories that has withstood the erosion and corrosion of progress. The objective of this presentation is to illustrate that an incomplete understanding of the Maxwellian physics can often lead to the wrong conclusions and could promise illusory designs. A few of them will be illustrated to start and initiate a dialog about the physical subtleties in the conception, analysis, and design of a wireless system. The topic will start with fundamental mathematical modeling, concept of diversity and how to employ ensemble averaging as its originator – James Clerk Maxwell, intended. It will also discuss the feasibility of baseband broadband communication and will describe adaptive processing techniques where the effect of near field scattering and mutual coupling between the antennas can be taken into account. Finally, a reciprocity based SISO system will be presented and contrasted in performance with a conventional MIMO system.

We first start the presentation with how to solve the nonlinear vector electromagnetic adaptive processing problem in contrast to the scalar quasi-linear acoustic problem. This new adaptive methodology can also take care of the various electromagnetic interactions between the antenna array and the platform on which it is mounted in addition to mutual coupling and nonuniformity in the antenna element spacing. To accomplish this goal a single snapshot based direct data domain least squares method is proposed which does not require any information of the clutter or noise characteristics and can be implemented in real time on a DSP chip. The number of coherent interferers that this method can handle is identical to the conventional adaptive techniques which require a block of data, whereas the classical method can deal with a larger number of incoherent interferers. Conventional approach in the electromagnetic community to adaptive antennas had employed analog processing techniques. With the advent of the digital technology the adaptive processing techniques used the conventional detection based methodology developed earlier for radar. The advantage of using the digital techniques is that one can cancel interferers in the main lobe. However, the detection based methodology is difficult to implement in real time as one needs to form a

covariance matrix of the data. Also the effect of the finite size antenna and the mutual coupling between the antennas and their surroundings had so far been neglected. The result is that one needs to carry out calibration before any processing of the data can be done and it is an important aspect of the processing that needs to be done repeatedly. However, in a modern high speed data flow environment what is necessary is a new approach to adaptive processing which is based on estimation rather than on detection which had been the primary approach in radar where the shape of the received signal is assumed to be known and dispersion do not play an important role. However, in a rich multipath environment, a detection based methodology is not the solution as we know there are many copies of the signal present and what we need to do is to estimate its correct value. In addition when an array operates in a near field environment it is not clear what antenna beam forming means as the antenna pattern can only be defined in the far-field! For an adaptive technique to operate in such complex dynamic electromagnetic environments we have proposed a Maxwellian approach to Adaptive Antenna [T. K. Sarkar, M. Wicks, M. Salazar-Palma and R. Bonneau, *Smart Antennas*, John Wiley & Sons, 2003]. The advantage of this approach is that it is quite amenable to a dynamic environment as we operate on a single snapshot of the data. It is rather important to note that for coherent interferers, the available degrees of freedom using a single snapshot of the data is identical to the conventional covariance based method of using multiple snapshots. In addition it is faster than the conventional methods by an order of magnitude and in addition no statistical knowledge of the clutter is necessary in the computation of this least squares solution. The following *FIVE* topics will be covered:

**Topic 1. A Direct Data Domain Least Squares Approach to Adaptive Processing**

The presentation will present a direct data domain least squares approach to adaptive processing without forming a covariance matrix which at least an order of magnitude faster than the stochastic methods, if and when they converge. Examples will be presented on the accuracy and efficiency of this technique over conventional stochastic methods for performing STAP processing using real measured data on an airborne platform called the MCARM data set.

**Topic 2. Adaptive Processing Using Directive Elements in the Presence of Near-Field Scatterers**

The talk will focus on how to adaptive processing using real antennas particularly when they are operating in a real environment in the presence of mutual coupling and other near field scatterers.

**Topic 3. Broadband Baseband Communication: Fact or Fiction !**

Current communication theory does not take the effect of antennas into account when talking about broadband – the result is a perfect recipe for failure- and the promise of baseband and broadband can only be addressed when the effects of sensors are appropriately accounted for. It will be shown that one can get a perfectly dispersionless channel once attention is paid to the physics of the problem which is sadly lacking in the present methodologies.

#### **Topic 4. Transmission and Reception by Ultrawideband Antennas in the Time Domain**

Impulse response of antennas in the time domain will be discussed. It will be shown that one needs a new paradigm to look at antennas in the time domain as opposed to in the frequency domain. Examples of various wideband antennas including the *century bandwidth antenna*, *impulse radiating antenna* and others will be presented.

#### **Topic 5. Signal Enhancement in a Near Field MIMO Environment Through Adaptivity on Transmit**

The definition of channel capacity a la Shannon is incomplete for the vector electromagnetic problem. The goal will be to address how to handle the vector electromagnetic problem as opposed to the scalar electromagnetic problem. The power spectral density which provides the basis for the scalar acoustics problem really does not hold in electromagnetics as the power in electromagnetics is defined by both the voltage and the current and not exclusively by either one, which may hold only for special cases. It is well known in electrical engineering that power in a RLC circuit cannot be obtained from only the voltage or the current. In addition the use of real antennas instead of point sources will drastically change the philosophy.