Practical and Theoretical Aspects of Time Reversal of Electromagnetic Waves

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Since 1990, the time reversal of ultrasonic waves is studied at laboratoire Ondes et Acoustique from Paris, France. Experimental as well as theoretical aspects of Time Reversal are explored.

Very recently, the first experiment of time reversal of microwave electromagnetic waves was performed at our laboratory. In this experiment, the time-reversed electromagnetic wave was focused on a single antenna. Since then, we have built two 8-antenna arrays that lead us to measure the spatial focusing. With this new set-up, it was essential to have a better understanding of all the aspects of time reversal of Electromagnetic waves. It exits only a few previous theoretical works on time reversal of electromagnetic waves. However most of the time, they only address a few particular aspects of time reversal of Electromagnetic Waves. Here we would like to propose a theory that makes the link between fundamental and technical aspects of time reversal. Thus in a first part, we discuss general aspects of reversibility of Maxwell Equation. We generalized the concept of time reversal cavity, first introduced in acoustic, to the case of electromagnetic waves. We show that the time-reversed wave is linked to the imaginary part of the dyadic Green's function. However this fundamental approach of time reversal is not sufficient since the electromagnetic wave field is generated and recorded by the way of antenna. Then we describe the time reversal experiment in terms of currents and potentials. The equivalent electric schema of a two-antenna time-reversal experiment is proposed. The influence of the two antennas is taken into account by the way of a 2 by 2 mutual impedance matrix. We recall the link that exists between impedance matrix and dyadic Green's function. The theory is then generalized to linear array of antennas. We show that the time-reversed wave on the array is linked to the real part of the mutual impedance. Technically, an antenna is always loaded, i.e., the antenna is connected to the ground by the way of impedance in order to provide an impedance matching. Therefore we explain the influence of such loads on the focusing. Most of our experiments are performed in a electromagnetic reverberant chamber. We show how the reverberation leads to retrieve the time-reversed Green's function even with a few time-reversal antennas. The presentation will be illustrated with experimental results and numerical results.