2nd URSI AT-RASC, Gran Canaria, 28 May – 1 June 2018

# An Interpretation of Time Reversal Invariant Systems

Marcos Rubinstein (1), Farhad Rachidi (2)
(1) University of Appl. Sciences Western Switzerland, Yverdon, e-mail: marcos.rubinstein@heig-vd.ch
(2) Swiss Federal Institute of Technology, Lausanne, e-mail: farhad.rachid@epfl.ch;

Time Reversal has gained attention in the past two decades as applications have been proposed and demonstrated in several fields of engineering [1] since it was developed in the 1990s by Fink and his team (e.g., [2]).
Time reversal is based on the invariance that numerous physics laws exhibit to the t-symmetry transformation, in which the time variable t is replaced by -t.

In the paper, we use a simple example to present three methods that allow an interpretation of the time reversal process, showing how TR can be used to make a system retrace the path it came from in the immediate past, effectively making it behave as if it were going back in time. The three methods are (i) the recording of the state of the system throughout its evolution from time $t=0$ to a time $t=t_m$, (ii) the use of expressions that describe the evolution of the system as a function of time, and, (iii) the imposition of initial conditions so that the system regresses, following its own natural defining equations, towards the states it went through in its past.
The developments lead us to introduce the concepts of time reversal in the strict and in the soft senses. A system is defined as being time-reversal invariant in the strict sense with respect to a physical quantity if, given a solution $f(t)$ of its underlying equations, the time-reversed function $g(t)$, given by $g(t) = f(-t + 2t_i)$, is also a solution. On the other hand, a system is time-reversal invariant in the soft sense if, given a solution $f(t)$ of its underlying equations, the time-reversed function $g(t)$ given above is also a solution of the underlying equation, but only after appropriate changes to the equations are applied. Examples of both types physical laws, including classical mechanics (TR -invariant in the hard sense) and Schrödiger Equation (TR-invariant in the soft sense) will be discussed. Possible applications, including lightning location will be presented [3], [4].

1. F. Rachidi, M. Rubinstein, and M. Paolone, *Electromagnetic Time Reversal: Application to EMC and Power Systems*. John Wiley & Sons, 2017.
2. M. Fink, “Time reversal of ultrasonic fields. I. Basic principles,” *IEEE Trans. Ultrason. Ferroelectr. Freq. Control*, vol. 39, no. 5, pp. 555–566, 1992.
3. N. Mora, F. Rachidi, and M. Rubinstein, “Application of the time reversal of electromagnetic fields to locate lightning discharges,” *Atmospheric Res.*, vol. 117, pp. 78–85, 2012.
4. G. Lugrin, N. M. Parra, F. Rachidi, M. Rubinstein, and G. Diendorfer, “On the location of lightning discharges using time reversal of electromagnetic fields,” *IEEE Trans. Electromagn. Compat.*, vol. 56, no. 1, pp. 149–158, 2014.