Alternative Directions to Control Spin Dynamics in Nuclear Magnetic Resonance and Physics

Eugene Stephane Mananga¹,²,³*

¹Ph.D Program Physics & Ph.D Program Chemistry, The Graduate Center, The City University of New York, USA
²Department of Applied Physics, New York University, USA
³Department of Engineering, Physics and Technology, The City University of New York, USA

As front-line theories to control spin dynamics in solid-state nuclear magnetic resonance, the Average Hamiltonian Theory (AHT) [1] and Floquet Theory (FLT) [2,3] have assumed great prominence and influence since the development of multiple pulse sequences and the inception of Magic-Angle Spinning (MAS) methods in the 1960s [4,5]. Methods developed over the past decade have enabled us to make a significant progress in the area of NMR by introducing an alternative expansion scheme called Floquet-Magnus Expansion (FME) [6,7] used to solve the time-dependent Schrodinger equation which is a central problem in quantum physics in general and solid-state NMR in particular. The FME establish the connection between the Magnus Expansion (ME) and the Floquet theory, and provides a new version of the ME well suited for the Floquet theory for linear ordinary differential equations with periodic coefficients [6-12]. We have proved that the ME is a particular case of the FME which yields new aspects not present in ME and Floquet theory such as recursive expansion scheme in Hilbert space that can facilitate the implementation of new or improvement of existing pulse sequences [6]. In the same vein, Madhu and Kurur has recently introduced the Fer Expansion (FE) in Solid-State NMR [13,14]. The Fer expansion was formulated by Fer [13] and later revised by Fer [13], Klarsfeld and Oteo [15], Casas, et al. [16] and Blanes, et al. [17]. This expansion employs the form of a product of sub-propagators, which appears to be suitable for examination of time-dependence of the density matrix for each average Hamiltonian at different orders. A paper which outlines the comparison of both theories (FME and FE) in NMR and physics has recently been published in the Journal of Physical Chemistry A [18].

Using the FME and FE approaches, many problems can be attacked in other fields of physics beyond the scope of NMR. It is important to remember that these considered methods have recently found new major areas of applications such as topological materials [19]. However, researchers dealing with these new applications are not usually acquainted with the achievements of the magnetic resonance theory, where those methods were developed more than thirty years ago [10,20-22]. Researchers repeat the same mistakes that were made when the methods of spin dynamics and thermodynamics were developed in the past. Even though the FME is a divergent approach in general, its finite truncation can gives useful information such as on the transient dynamics in periodically driven many-body quantum systems [22,23]. New avenues of exploring FME and FE can also be extended to other areas of physics such as particles and high energy physics [20,21]. These two approaches (FME and FE) can be used to solve problems in Quantum Field Theory (QFT) and high energy physics, in particular problems similar to the one solved or fail to be solved by ME. For instance,

1. The ME has been used as an alternative to conventional perturbation theory for quantum fields to graph rules for functions of the time-evolution operator where normal products and Wick theorem were used. This was useful in the treatment of infrared divergences for some quan-

*Corresponding author: Eugene Stephane Mananga. Department of Engineering, Physics and Technology, The City University of New York, 2155 University Avenue, CPH 118, Bronx, 10453, New York, USA, Tel: +1-646-345-4613, Fax: +1-718-289-6403, E-mail: esm041@mail.harvard.edu; emananga@gradcenter.cuny.edu

Received: July 06, 2017; Accepted: August 31, 2017; Published: September 02, 2017

Copyright: © 2017 Mananga ES. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

Citation: Mananga ES (2017) Alternative Directions to Control Spin Dynamics in Nuclear Magnetic Resonance and Physics. Int J At Nucl Phys 2:005
tum electrodynamics process such as the scattering of an electron on an external potential or the bremsstrahlung of one hard photon [24,25]. I believe that effective method of approaching this problem demands more inspection where FME and FE can play a major role. The calculation of effective Hamiltonians has been used with great success in many areas of physics such as high resolution NMR spectroscopy [8-12], the topological states of Floquet in graphene and semi-metals under the action of external electromagnetic fields [26-31], in superfluid systems [32-35], in systems discretized spatially by the presence of the lattice [36-38], in the periodically driven systems, among others. In the calculation of effective Hamiltonians, several different models are used, namely: the method of multi-temporal scales or the Floquet-Magnus and Fer expansions which are of our interest in this review. An infrared divergence in physics is a position in which an integral such as a Feynman diagram, diverges because of contributions of objects with very small energy approaching zero due to physical phenomena at very long distances. In particle physics, quantum electrodynamics is the relativistic quantum field theory of electrodynamics delineating how light and matter interact and is the first theory where full agreement between quantum mechanics and special relativity is concluded. The time independent Hamiltonian of FME [39-42] and FE [43] can then play a major role in the treatment of infrared divergences for some quantum electrodynamics process.

2. An extension of the ME has been applied to the context of Connes-Kreimer’s Hopf algebra approach to perturbative renormalization of quantum field theory showing that the generalized ME [44,45] allows to solve the Bogoliubov-Atkinson recursion [46]. The FME and FE can also be applied in this context.

3. In the field of high energy physics, ME has also found applications such as to heavy ion collisions. ME is applied in collision problems when the use of unitary approximation scheme is necessary such as the unitary of the time evolution operator imposing some bound on the experimentally observable cross sections [47,48]. FME and FE can also be used in this context as an intuitive method for simplifying calculations.

4. The problem in neutron oscillations which is closely related to solar neutrino problem. As neutrinos with different masses propagate with different velocities, the mixing allows for flavor conversion corresponding to neutrinos oscillations [48-50]. Fer’s factorization as a symplectic integrator can, in principle, enter in the solution of the evolution operator in one basis.

The introduction of FME and FE as theoretical approaches to control the spin dynamics in the field of nuclear magnetic resonance is a new exploratory and developmental research which is a significant addition to the existing theoretical framework of AHT and FT. QFT is the basic mathematical language used to describe and analyze the physics of elementary particles. The theory by itself is an abstract representation for constructing quantum mechanics models of subatomic particles in particle physics and quasi particles in condensed matter physics. The application of the FME and FE approaches as intuitive approaches in simplifying calculations to solve some specific problems in the field of high energy physics and QFT such as those outlined in the above paragraph is of major interest. It is worth noting that, the FME has the advantage of having the unitary character of the evolution operator which is preserved at all orders of approximation while the FE has an advantage over the ME that only an evaluation of nested commentators is required in the calculation of the Hamiltonian [14].

References


