The phenomenological dissipation of the Bloch equations is reexamined in the context of completely positive maps. Such maps occur if the dissipation arises from a reduction of a unitary evolution of a system coupled to a reservoir. In such a case the reduced dynamics for the system alone will always yield completely positive maps of the density operator. We show that, for Markovian Bloch maps, the requirement of complete positivity imposes some Bloch inequalities on the phenomenological damping constants. For non-Markovian Bloch maps some kind of Bloch inequalities involving eigenvalues of the damping basis can be established as well. As an illustration of these general properties we use the depolarizing channel with white and colored stochastic noise.

Introduction In 1946, Felix Bloch introduced a set of equations describing the dynamics of a nuclear induction of a spin that interacts with a magnetic field bloch1946. The applied magnetic field drives the Bloch vector of the magnetic moment, causing it to precess about the field direction. In addition to the unitary evolution describing the magnetic moment precession, a nonunitary evolution is observed in nuclear magnetic resonance, which results in dissipation of the magnetic observables. This dissipation is characterized by two phenomenological decay constants. The two lifetimes $T_1$ and $T_2$ are the longitudinal and transverse decay constants, respectively.

Fluctuations in the environment, such as inhomogeneities in the magnetic field and interactions with other moments, lead to dissipation in the system. The dissipation constants $T_1$ and $T_2$ are nonnegative so that exponential decay of the magnetic moment occurs. It is well known that this condition is required to preserve the positivity of the density operator under dissipation. The phenomenological dissipation of the Bloch vector defines a positive map (PM) of the density operator for the spin system.

About the physical sources of the dissipation constants Bloch wrote: quote The actual value of $T_1$ is very difficult to predict for a given substance ... To give a reliable estimate of $T_2$ ... requires a more detailed investigation of the mechanism involved and will not be attempted here.