constructive interference in steady-state CISS

In the context of MRI pulse sequences, the term ‘steady state’ typically refers to the equilibrium condition that evolves when magnetization experiences a train of radiofrequency (RF) pulses. If RF pulses occur at broadly spaced intervals (repetition time [TR] > T1), the magnetization recovers fully between pulses due to relaxation, and the steady-state is identical to the fully relaxed magnetization, M0. However, in general, RF pulses are applied sufficiently rapidly that the magnetization does not recover fully between pulses (TR < T1), and the magnetization eventually develops a steady-state condition that is distinct from M0.

For most MRI pulse sequences, TR is on the order of seconds, making it of similar magnitude to T1, but much longer than T2. In this case, at the end of the TR, the magnetization has decayed away completely in the transverse plane, but has not yet recovered fully along the longitudinal axis. The result is a ‘longitudinal steady state’, where the magnetization tipped away from the longitudinal axis by an RF pulse is exactly cancelled by recovery of magnetization along the longitudinal axis during the TR. Longitudinal steady states depend on the T1 of tissue, but not T2.

However, ‘steady-state sequences’ commonly refer to a more specific case in which both T1 and T2 relaxation are interrupted by very rapid RF pulses (TR ≤ T2 < T1). In this situation, there is residual transverse magnetization at the end of the TR, which experiences the subsequent RF pulse. We would describe the result as a ‘transverse steady state’ (with the understanding that this necessarily implies steady state of the longitudinal component, as well). Again, we can determine the steady state by imposing the equilibrium condition that the effects of relaxation and precession of the magnetization during the TR must be exactly cancelled by the RF pulse.

The signal dynamics of steady-state sequences are considerably more complicated than conventional sequences, and depend on T1, T2 and the phase (angle) between the magnetization and the axis of the RF pulse. In fact, it is the dependence of the steady state on phase that leads to the tremendous richness and flexibility of steady-state sequences, as well as many of the complications in dealing with these methods.