CC/NUMBER 38
SEPTEMBER 22, 1980

This Week's Citation Classic

Meiboom S & Gill D. Modified spin-echo method for measuring nuclear relaxation times. *Rev. Sci. Instr.* **29**:688-91, 1958.[Dept. Applied Math.,Weizmann Institute of Science, Rehovot, Israel]

This paper describes an improved NMR method for measuring long T_2 relaxation times in liquids. In essence, the introduction of controlled phase relationships in the pulse train of the Carr-Purcell scheme greatly improves the accuracy of the method. [The *SCI*® indicates that this paper has been cited over 340 times since 1961.]

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August 20, 1980

"The work leading to this paper was done nearly 25 years ago at the Weizmann Institute of Science, Rehovot, Israel. David Gill, who was then a graduate student (he is at present on the faculty of Beersheba University), set out to measure NMR T_2-relaxation times in liquids, using the well-known Carr-Purcell pulse train scheme.[1,2] He soon found that at high pulse repetition rates adjustments became very critical, and echo decays, which ideally should be exponential, often exhibited beats and other irregularities. But he also saw that on rare and unpredictable occasions a beautiful exponential decay was observed (after an initial messy transient). Though my recollection of the events from here on is vague at best, I do recall that there was quite some discussion on the possible causes of this effect, from which somehow the recognition emerged that the chance occurrence of a 90° phase shift of the nuclear polarization must underlie the observations. It became clear that in the presence of such a shift a stable, self-correcting state of the nuclear polarization is produced, while the original scheme results in an unstable state, for which deviations are cumulative. From here it was an easy step to the introduction of an intentional phase shift in the applied pulse train, and the consistent production of good decays.

"Although in hindsight the 90° phase shift seems the logical and almost obvious thing to do, its introduction was triggered by a chance observation, rather than by clever a *priori* reasoning. I suspect (though I have no proof) that this applies to many scientific developments, even if the actual birth process of a new idea is seldom described in the introduction to the relevant paper.

"Why has this article been cited relatively often? I can think of two factors: (1) The Carr-Purcell scheme, with phase shift added, is still the preferred method for measuring long T_2's in liquids, and (2) more recently a variety of pulse methods,[3] sometimes with quite complex pulse sequences, have been proposed to achieve special goals, for instance eliminating dipolar interactions in solids. In most of these methods it is essential to control phase relations. Our paper may have been quoted because, to the best of my knowledge, it was the first to point out the importance of maintaining specific phase relations in NMR pulse methods."

1. **Hahn E L.** Spin echoes. *Phys. Rev.* **80**:580-94, 1950.
2. **Can H Y & Purcell E M.** Effects of diffusion on free precession in nuclear magnetic resonance experiments. *Phys. Rev.* **94**:630-8. 1954.
3. **Haeberlen U.** High resolution NMR in solids. *Advan. Magn. Reson. Suppl. 1* **1976**:1-190. 1976.