**Article title:** Noise spectroscopy of a quantum-classical environment with a diamond qubit

**Authors:** S. Hernández-Gómez, F. Poggiali, P. Cappellaro, and N. Fabbri

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**Context**

In any quantum computing system, the qubits will have some interaction with their environment, which causes unwanted decoherence and loss of quantum information. One method for combatting this loss is dynamic decoupling, where a sequence of resonant optical or microwave pulses is applied to the qubit. The authors cite one particular dynamic decoupling scheme, where the sequence is optimized based on the frequency spectrum of the environmental noise (their ref. 2), saying that this type of optimised sequence better decouples the qubit from the environment.

**Purpose**

For an optimised sequence, you first need to know the noise spectrum of the environment. There are existing techniques for measuring noise spectra, but say that these techniques are limited because they generally assume the environment is classical (i.e. can be modeled as some sort of stochastic perturbative field) and that the coherence time is long relative to the coupling. Their paper demonstrates a technique that does not require these assumptions.

**Approach**

They say they present a protocol for characterising the noise environment, and experimentally implement it for a system consisting of a nitrogen-vacancy centre qubit with a environment of the naturally occurring carbon-13 nuclear spins, which interact with the qubit with a strength depending on their distance from the qubit. Strongly interacting carbon-13 are part of a quantum bath, and weakly interacting ones are part of a classical bath. They say they can experimentally tune how much of the decoherence is due to the quantum and to the classical bath with a magnetic field, although I don’t see how. I can’t see where they define their protocol, either. They reference other papers (their refs 14, 15) that talk about measuring noise spectra with dynamic decoupling, and mention the XY-8 existing protocol, but do not define theirs clearly.

**Contribution**

They say that their protocol accurately predicts the behaviour of the NV qubit when they apply more complex pulse sequences as long as the bath is mostly classical, but increasingly fails for more quantum baths because they interact with the qubit. They say they probably could model the quantum case well for an individual complex pulse sequence using a technique in their reference 47. It is not entirely clear how this fits into the field- there are other papers looking at dynamic decoupling for both classical and quantum baths. Perhaps it is that they allow both at once.

**Relevance**

I’m interested in how you design dynamic decoupling schemes to decouple qubits from particular elements of the environment, particularly the quantum bath, because that dominates decoherence in our qubits. I don’t think this paper itself is super useful, but it references a lot of recent work which does look more promising (e.g. refs 14, 15).

**Quality**

The introduction of the paper is well written but the body is very unclear, and lots of information seems to be missing (e.g. what their protocol is!). Virtually all their references are less than 10 years old, which is suspicious given dynamic decoupling is ~40 years old. Their protocol seems a bit basic, and I’m a little dubious of how important this result is, because they don’t put it in context of other similar results.

**Questions/Directions**

* What exactly is their protocol, and how is this significantly different from other approaches?
* I could talk to an NV person about why tuning the magnetic field makes the bath more or less classical.
* Use the recent references as a starting point for understanding modern dynamic decoupling work