Supplementary Information for:
"High resolution quantum sensing with shaped control pulses"

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Computation of the cosine square pulse waveform

The following Matlab code was used to calculate the amplitude modulation for a dynamical decoupling sequence with `N` shaped pulses, as shown in Figure 1(a) and 1(c) of the main manuscript:

```
x = (0:n-1)*N/n;
x = mod(x,1);
x = 1-tau/tpi*abs(x-0.5);
x = max(x,0);
x = sin(pi*x/2).^2;
```

Here, `n` is the number of waveform samples, `tau` is the interpulse delay, and `tpi` is the duration of a π pulse defined as the full width at half maximum of the envelope function. Note that with this definition of `tpi`, the duration of a cosine-shaped π pulse is equal to the duration of an equivalent square pulse with the same peak amplitude. In our experiments, `N` was up to 26,000, `n` was up to about 500,000, and `tpi` was about 25 ns.

The resulting waveform envelope is then software multiplied with a carrier sine wave at 100 MHz, and upconverted to the ~ 2.2 GHz spin resonance by analog IQ mixing with the output of an external synthesizer.

Comparison of filter functions for dynamical decoupling sequences with different pulse shapes

To investigate whether the type of control pulse used has an influence on the filter function of a dynamical decoupling sequence, we simulated the response of the sequence to a single ^{13}C nucleus using the density matrix method [1, 2]. For this example, we used the same parameters as for the ^{13}C in Fig. 4(b) of the main manuscript. The π pulse duration was $t_\pi = 25\,\mathrm{ns}$, the ^{13}C Zeeman frequency was 1.975 MHz, and the detuning of the NV electronic spin due to the ^{15}N nuclear was taken into account.

We simulated the responses of sequences using four different control pulses: ideal, square, cosine-square-shaped, and cosine-square-shaped rounded to 14 bits. Figure 1(a) shows the response for the sequence with ideal (infinitely short and exact) π rotations. Figure 1(b) plots the difference to the ideal response when using square pulses (blue curve) and when using cosine-square-shaped pulses (red curve). We find that there is a difference to the ideal response, but that the difference between the square and cosine-square control pulses is small. The differences are mainly due to the rather low Rabi frequency ($\sim 20\,\mathrm{MHz}$) which results in comparably long pulses and different phase pickup between ideal, square and cosine-square sequences. We have also simulated the response to cosine-square pulses with a discrete amplitude, reflecting the 14 bits of vertical resolution of the AWG; here, the difference in p is $< 10^{-6}$ (not shown).

[1] M. Loretz, J. M. Boss, T. Rosskopf, H. J. Mamin, D. Rugar, and C. L. Degen, Phys. Rev. X **5**, 21009 (2015), URL http://dx.doi.org/10.1103/PhysRevX.5.021009.

[2] J. M. Boss, K. Chang, J. Armijo, K. Cujia, T. Rosskopf, J. R. Maze, and C. L. Degen, Phys. Rev. Lett. **116**, 197601 (2016).

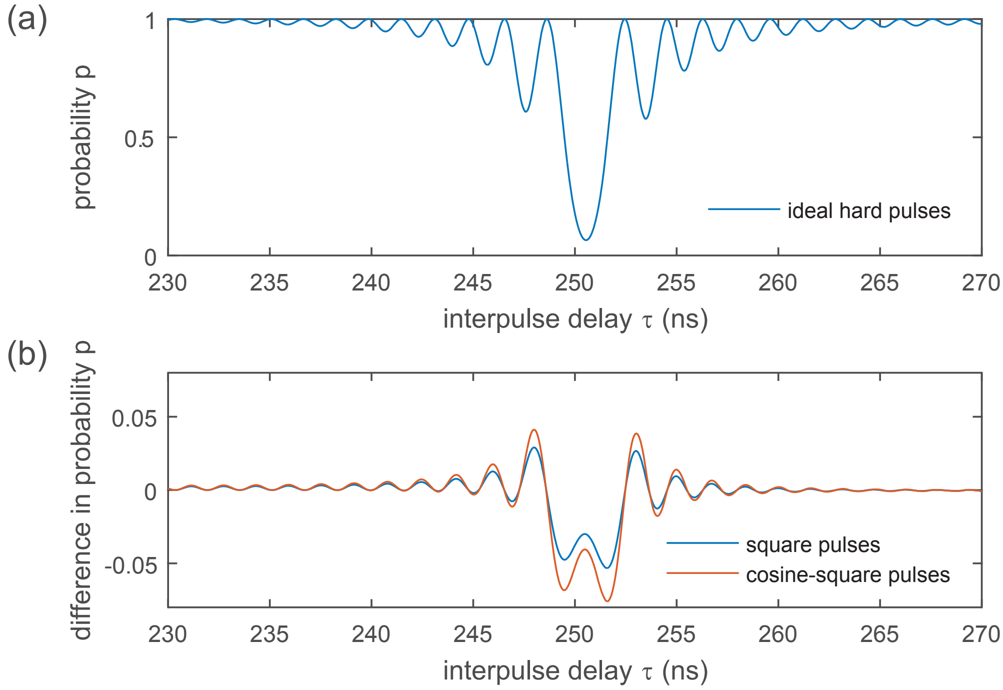

FIG. 1: Simulated response of a dynamical decoupling sequence with $N = 320$ pulses to a single ^{13}C nuclear spin. (a) Response of a sequence with ideal π pulses. (b) Response of the sequences with square and cosine-square-shaped π pulses, respectively. Shown is the difference to the ideal response.