Ultra broadband decoupling methods: CHIRP,[1] WURST[2]

Recently, adiabatic pulse methods, such as CHIRP and WURST (Wideband, Uniform Rate, and Smooth Truncation), are used for ultra broadband decoupling. These pulses can invert magnetizations in extremely wide ranges by modulating phases of pulses, according to the following equation:

$$\phi(t) = \phi_0 + \frac{1}{2}kt^2$$

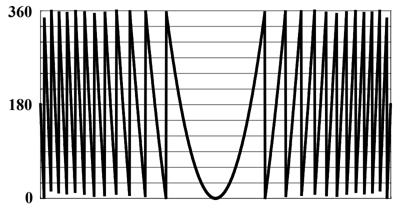

Fig. 1 Phase modulation of 200 kHz range and 1 ms pulse width.

where k is a modulation rate, range (Hz)/pulse width (s), and t is an instantaneous time during the pulse. CHIRP and WURST pulses, involving a parameter of the sweep width, should be reconstructed depending on the measurement conditions. ECA series automatically generate shaped pulses from their definition, and so adiabatic pulses are created only by giving the parameters. In WURST, the edges of the profile are smoothed by blunting responses of both ends of the swept range. To realize this, the pulse is shaped like a sausage (wurst in German) by modulating amplitudes as:

$$\omega_1(t) = \omega_1(\max)\left\{1 - \left|sin(\beta t)\right|^n\right\}$$

Fig. 2 Amplitude modulation of n=20.

where $-\pi/2 < \beta t < \pi t$, and the order n specifies the steepness of the slope. The above graph shows the amplitude modulation of n=20, while both ends become gradual as the order decreases.

Actual WURST decoupling consists of MLEV4 composite pulses of Tycko and Pines' 5-step phase cycle, $RR\bar{R}\bar{R}$ ($R=SP_0\ SP_{150}\ SP_{60}\ SP_{150}\ SP_0$), reaching the length of 20 pulse widths. Figure 3 shows the WURST decoupling profile for 200 kHz range and 1 ms pulse width, demonstrating approximately 150 kHz decoupling. Thus, adiabatic pulses can decouple in very wide ranges.

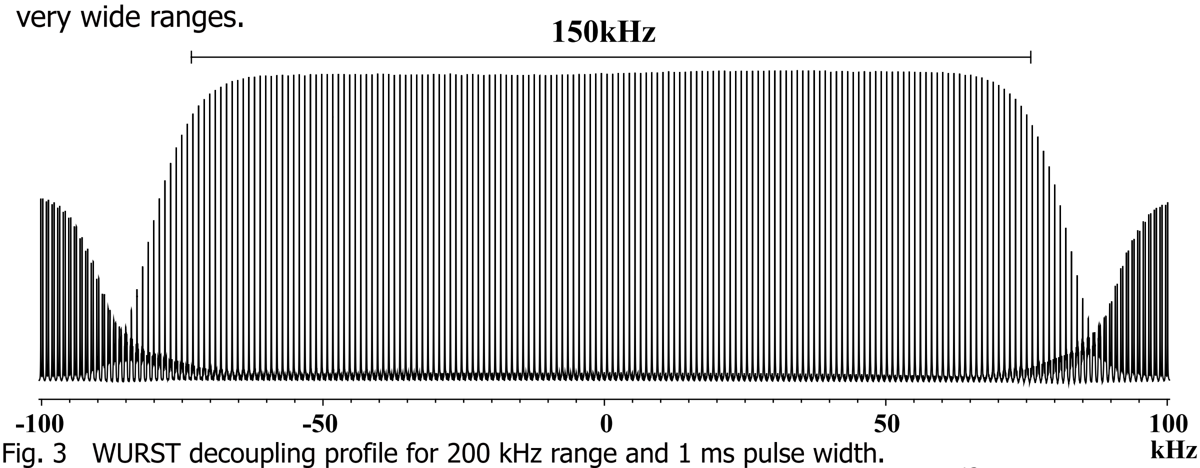

Fig. 3 WURST decoupling profile for 200 kHz range and 1 ms pulse width.

Sample: ^{13}C enriched methanol
Spectrometer: JNM-ECA500

Reference
1) R.Fu, and G. Bodenhausen, Chem. Phys. Lett. 245, 415(1995)., R.Fu, and G. Bodenhausen, J. Magn. Reson. A 117, 324(1995).
2) E. Kupce, and R. Freeman, J. Magn. Reson. A 115, 273(1995)., E. Kupce, and R. Freeman, J. Magn. Reson. A 117, 246(1995)., E. Kupce, and R. Freeman, J. Magn. Reson. A 118, 299(1996).