SUPPORTING INFORMATION

Section S1. Product operator analysis of the PDI-1 pulse sequence in Fig. 1a

- The analysis is for the antiecho part in a ^{13}CH-^{13}CH spin system with I and S representing ^{1}H and ^{13}C spins, respectively.
- Irrelevant terms are dropped along the way in the analysis, particularly those leading to transverse S-spin operators after the central pair of $(\pi/2)_y(H)$ and $(\pi/2)_{-y}(C)$ pulses. Terms in red are dropped in the succeeding step of the analysis.
- The delays τ and 2d are tuned exactly to $0.5/^1J_{CH}$
- The two sets of simultaneous refocusing pulses of the back-transfer sequence are respectively condensed into the preceding pair of $(\pi/2)_x(H,C)$ and the final $(\pi/2)_x(H)$ pulse.
- The normalization and scaling of the individual density operators are chosen for convenience and is not consistent.
- The terms in black are modulated by the chemical shift frequency of spin S_2 whilst the blue ones are modulated by chemical shift frequency of spin S_1.
- For symmetry reasons it suffices to analyze magnetization originating from one of the protons.

Right before the 2π/3 pulse:

$$\sigma_1{:}4I_{1z}S_1^+S_2^+$$

Right after the 2π/3 pulse and including the effect of the succeeding ^{13}C π pulse:

$$\sigma_2{:}4I_{1z}S_1^+S_{2z}+4I_{1z}S_{1z}S_2^+=4I_{1z}S_{1x}S_{2z}+i4I_{1z}S_{1y}S_{2z}+4I_{1z}S_{1z}S_{2x}+i4I_{1z}S_{1z}S_{2y}$$

At the end of the τ_C delay:

$$\sigma_3{:}[4I_{1z}S_{1x}S_{2z}+i4I_{1z}S_{1y}S_{2z}]cos(\pi J_{CC}\tau_C)+[2I_{1z}S_{1y}-i2I_{1z}S_{1x}]sin(\pi J_{CC}\tau_C)+$$
$$[4I_{1z}S_{1z}S_{2x}+i4I_{1z}S_{1z}S_{2y}]cos(\pi J_{CC}\tau_C)+[2I_{1z}S_{2y}-i2I_{1z}S_{2x}]sin(\pi J_{CC}\tau_C)$$

Right after $(\pi/2)_{-x}$(H,C):

$$\sigma_4{:}[4I_{1y}S_{1x}S_{2y}-i4I_{1y}S_{1z}S_{2y}]cos(\pi J_{CC}\tau_C)+[-2I_{1y}S_{1z}-i2I_{1y}S_{1x}]sin(\pi J_{CC}\tau_C)+$$
$$[4I_{1y}S_{1y}S_{2x}-i4I_{1y}S_{1y}S_{2z}]cos(\pi J_{CC}\tau_C)+[-2I_{1y}S_{2z}-i2I_{1y}S_{2x}]sin(\pi J_{CC}\tau_C)$$

At the end of the 2d delay:

$$\sigma_5{:}[-8I_{1y}S_{1x}S_{2x}I_{2z}-i4I_{1x}S_{2x}I_{2z}cos(\pi J_{CC}2d)]cos(\pi J_{CC}\tau_C)+[I_{1x}-i2I_{1y}S_{1x}cos(\pi J_{CC}2d)]sin(\pi J_{CC}\tau_C)+$$
$$[8I_{1y}S_{1y}S_{2y}I_{2z}+i2I_{1y}S_{1x}sin(\pi J_{CC}2d)]cos(\pi J_{CC}\tau_C)+[4I_{1x}S_{1z}S_{2z}-i4I_{1x}S_{2x}I_{2z}sin(\pi J_{CC}2d)]sin(\pi J_{CC}\tau_C)$$

Right after $(\pi/2)_y$(H) and $(\pi/2)_{-y}$(C):

$$\sigma_6{:}[-8I_{1y}S_{1z}S_{2z}I_{2x}+i4I_{1z}S_{2z}I_{2x}cos(\pi J_{CC}2d)]cos(\pi J_{CC}\tau_C)+[-I_{1z}-i2I_{1y}S_{1z}cos(\pi J_{CC}2d)]sin(\pi J_{CC}\tau_C)+$$
$$i2I_{1y}S_{1z}sin(\pi J_{CC}2d)cos(\pi J_{CC}\tau_C)+i4I_{1z}S_{2z}I_{2x}sin(\pi J_{CC}2d)sin(\pi J_{CC}\tau_C)$$

At the end of the τ delay:

$$\sigma_7{:}[2I_{1x}I_{2y}+i2I_{1z}I_{2y}cos(\pi J_{CC}2d)]cos(\pi J_{CC}\tau_C)+[-I_{1z}+iI_{1x}cos(\pi J_{CC}2d)]sin(\pi J_{CC}\tau_C)$$

$$- iI_{1x}sin(\pi J_{CC}2d)cos(\pi J_{CC}\tau_C) + i2I_{1z}I_{2y}sin(\pi J_{CC}2d)sin(\pi J_{CC}\tau_C)$$

Right after (π/2)$_{-x}$(H) and including the effect of the final ^{1}H π pulse:

$$\sigma_8: [2I_{1x}I_{2z} - i2I_{1y}I_{2z}cos(\pi J_{CC}2d)]cos(\pi J_{CC}\tau_C) + [I_{1y} + iI_{1x}cos(\pi J_{CC}2d)]sin(\pi J_{CC}\tau_C)$$
$$- iI_{1x}sin(\pi J_{CC}2d)cos(\pi J_{CC}\tau_C) - i2I_{1y}I_{2z}sin(\pi J_{CC}2d)sin(\pi J_{CC}\tau_C)$$

Back to raising and lowering operators and keeping only the latter:

$$\sigma_8: \quad \frac{1}{2}2I_1^-I_{2z}(1 + cos(\pi J_{CC}2d))cos(\pi J_{CC}\tau_C) + \frac{i}{2}\{I_1^-sin(\pi J_{CC}\tau_C)(1 + cos(\pi J_{CC}2d))\}$$
$$- \frac{i}{2}I_1^-sin(\pi J_{CC}2d)cos(\pi J_{CC}\tau_C) + \frac{1}{2}2I_1^-I_{2z}sin(\pi J_{CC}2d)sin(\pi J_{CC}\tau_C)$$

In summary:

PDI peaks: $\left\{\frac{i}{2}I_1^-sin(\pi J_{CC}\tau_C) + \frac{1}{2}2I_1^-I_{2z}cos(\pi J_{CC}\tau_C)\right\}(1 + cos(\pi J_{CC}2d))$

HSQC peaks: $\left\{-\frac{i}{2}I_1^-cos(\pi J_{CC}\tau_C) + \frac{1}{2}2I_1^-I_{2z}sin(\pi J_{CC}\tau_C)\right\}sin(\pi J_{CC}2d)$

or split up on the two doublet components:

PDI peaks: $\left\{I_1^-I_2^{\alpha}e^{i\pi J_{CC}\tau_C} - I_1^-I_2^{\beta}e^{-i\pi J_{CC}\tau_C}\right\}(1 + cos(\pi J_{CC}2d))$

HSQC peaks: $-i\left\{I_1^-I_2^{\alpha}e^{i\pi J_{CC}\tau_C} + I_1^-I_2^{\beta}e^{-i\pi J_{CC}\tau_C}\right\}sin(\pi J_{CC}2d)$

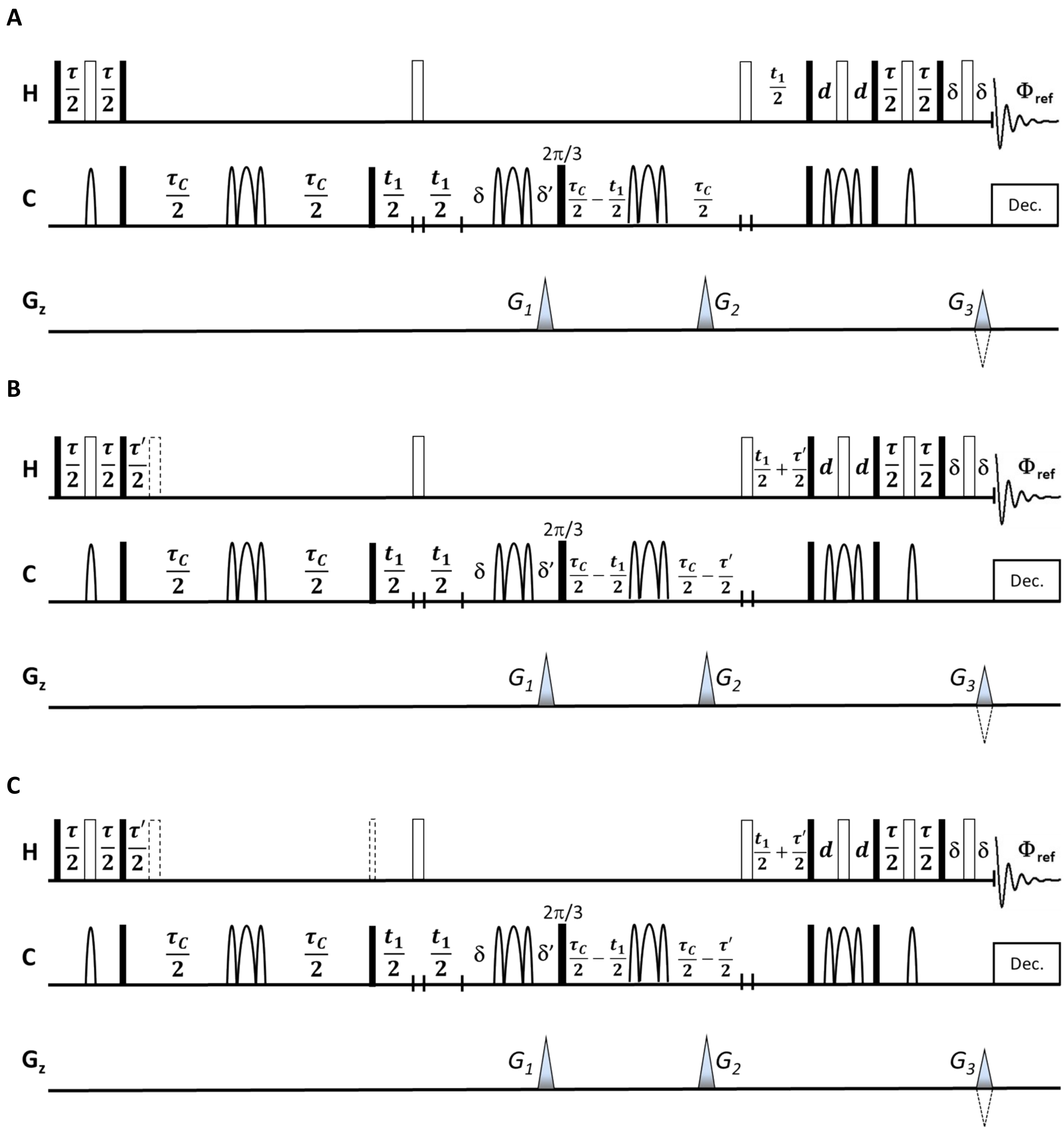

Figure S1. The three PDI-1 SQ NMR pulse sequences in Fig. 1 outlined separately. **A.** The one described by Reif et al. **B.** Refocused version. **C.** Refocused version with a ^{1}H purging pulse prior to t_1. Further details are in the Fig. 1 caption.

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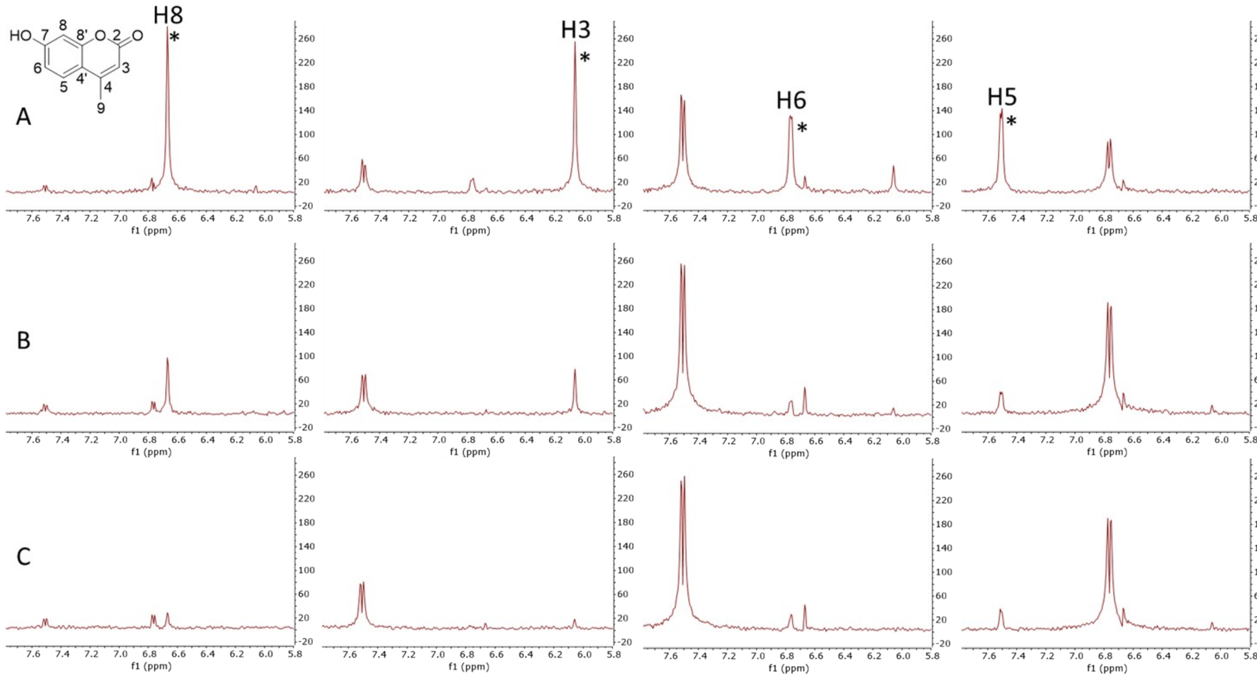

Figure S2. F_2 sections through HSQC artifacts (*) designated in Figure 1 by shaded circles illustrating progressive suppression of these artifacts by the A-C versions of PDI-1 SQ in Fig.1 or Fig. S1 A-C. Data are shown in absolute value mode.

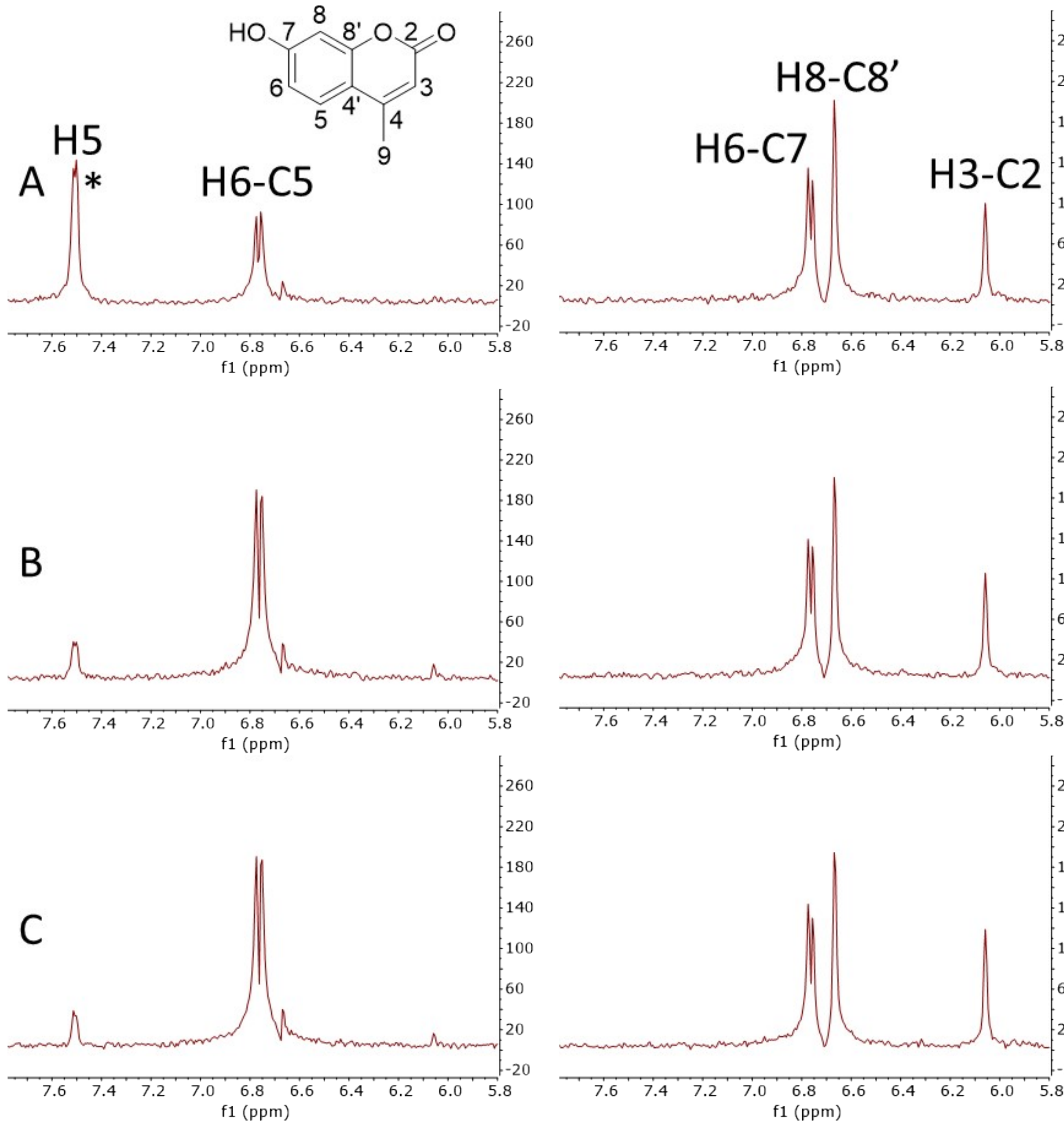

Figure S3. F_2 sections taken at the positions of the dashed lines in Figure 1 A-C illustrating about 2x sensitivity gain for the methine-methine H6-C5 PDI correlation in B and C and the about equal sensitivity for H6-C7, H8-C8', and H3-C2 methine-quaternary correlations. The * indicates the H5-C5 HSQC artifact. Data are shown in absolute-value mode.

Section S2. Pulse program for PDI experiment described in Figure 1B.

```
;adeq_PDI_1.tw
;avance-version (15/02/27)
; 2D-HSQC-1J(CC)-ADEQUATE
;   with refocussing of C chemical shift
;   using sensitivity improvement
;phase sensitive using Echo/Antiecho gradient selection
;with decoupling during acquisition
;using shaped pulses for 180degree pulses on f2 - channel
;
;B. Reif, M. Koeck, R. Kerssebaum, H. Kang, W. Fenical & C. Griesinger
;   J. Magn. Reson. A118, 282-285 (1996).
;M. Koeck, R. Kerssebaum & W. Bermel, Magn. Reson. Chem. 41, 65-69 (2003)
;
;$CLASS=HighRes
;$DIM=2D
;$TYPE=
;$SUBTYPE=
;$COMMENT=


#include <Avance.incl>
#include <Delay.incl>
#include <Grad.incl>


"p2=p1*2"
"d0=3u"
"d11=30m"

"p0=p3*1.333"
"d4=1s/(cnst2*4)"
"d23=1s/(cnst3*4)"
"d24=1s/(cnst2*cnst11)"


"in0=inf1/2"

"in20=in0"

"d20=d23-4u"

"td1=tdmax(td1,d20*2,in20)"
```

```
"DELTA1=p16+d16-p2-d0*2+4u"
"DELTA2=p16+d16+6u"
"DELTA3=d23-d4-p16-d16-4u-p2-d0"
"DELTA4=d4-p14/2-4u"
"DELTA5=d23-p24/2-4u"
"DELTA6=d24-cnst17*p24/2-4u"
"DELTA7=d4-4u"
"DELTA8=d23-d4-p2-p24/2-4u"


1 ze
  d11 pl12:f2
2 d1 do:f2
3 (p1 ph1)
  4u
  DELTA4 pl0:f2
  (center (p2 ph1) (p14:sp3 ph1):f2 )
  4u
  DELTA4 pl2:f2
  (p1 ph2) (p3 ph4):f2
  4u
  DELTA7 pl2:f2
  (p2 ph1)
  4u
  DELTA8 pl0:f2
  (p24:sp7 ph8):f2
  4u
  DELTA5 pl2:f2
  (p3 ph9):f2
  d0
  (p2 ph1)
  d0
  DELTA1 pl0:f2 UNBLKGRAD
  (p24:sp7 ph11):f2
  4u
  p16:gp1
  d16 pl2:f2
  (p0 ph10):f2
  4u
  d20 pl0:f2
  (p24:sp7 ph11):f2
  4u
```

```
  p16:gp2
  d16
  DELTA3 pl2:f2
  (p2 ph1)
  d0
  d4
  (center (p1 ph1) (p3 ph5):f2 )
  4u
  DELTA6 pl0:f2
  (center (p2 ph1) (p24:sp7 ph1):f2 )
  4u
  DELTA6 pl2:f2
  (center (p1 ph2) (p3 ph6):f2 )
  4u
  DELTA4 pl0:f2
  (center (p2 ph1) (p14:sp3 ph1):f2 )
  4u
  DELTA4
  (p1 ph1)
  DELTA2
  (p2 ph1)
  3u
  p16:gp3*EA
  d16 pl12:f2
  3u BLKGRAD
  go=2 ph31 cpd2:f2
  d1 do:f2 mc #0 to 2 F1EA(calgrad(EA) & calph(ph6, +180), caldel(d0, +in0) & caldel(d20, -in20))
exit


ph1=0
ph2=1
ph4=0 2
ph5=0 0 2 2
ph6=1 1 3 3
ph7=0
ph8=0
ph9=1 1 1 1 3 3 3 3
ph10=1 1 1 1 1 1 1 1 3 3 3 3 3 3 3 3
ph11=0
ph31=0 2 2 0 2 0 0 2 2 0 0 2 0 2 2 0


;pl0 : 0W
```

;pl1 : f1 channel - power level for pulse (default)
;pl2 : f2 channel - power level for pulse (default)
;pl12: f2 channel - power level for CPD/BB decoupling
;sp3: f2 channel - shaped pulse (180degree inversion)
;spnam3: Crp60,0.5,20.1
;sp7: f2 channel - shaped pulse (180degree refocussing)
;spnam7: Crp60comp.4
;p0 : f2 channel - 120 degree high power pulse
;p1 : f1 channel - 90 degree high power pulse
;p2 : f1 channel - 180 degree high power pulse
;p3 : f2 channel - 90 degree high power pulse
;p14: f2 channel - 180 degree shaped pulse for inversion
;   = 500usec for Crp60,0.5,20.1
;p16: homospoil/gradient pulse
;p24: f2 channel - 180 degree shaped pulse for refocussing
;   = 2msec for Crp60comp.4
;d0 : incremented delay (2D)   [3 usec]
;d1 : relaxation delay; 1-5 * T1
;d4 : 1/4J(CH)
;d11: delay for disk I/O   [30 msec]
;d16: delay for homospoil/gradient recovery
;d20: d23 - 4u
;d23: 1/(4J(CC))
;d24: 1/(4J(CH)) for CH
;   1/(8J(CH)) for all multiplicities
;cnst2 : J(CH) = 127 .. 160 Hz
;cnst3 : J(CC) = 35 .. 55 Hz
;cnst11: for multiplicity selection = 4 for CH, 8 for CHn
;cnst17: = -0.5 for Crp60comp.4
;inf1: 1/SW(C) = 2 * DW(C)
;in0: 1/(2 * SW(C)) = DW(C)
;nd0: 2
;in20: = in0
;ns: 16 * n
;ds: >= 16
;td1: number of experiments
;FnMODE: echo-antiecho
;cpd2: decoupling according to sequence defined by cpdprg2
;pcpd2: f2 channel - 90 degree pulse for decoupling sequence

;for z-only gradients:
;gpz1: +78.5%
;gpz2: +77.6%

```
;gpz3: -59%

;use gradient files:
;gpnam1: SMSQ10.100
;gpnam2: SMSQ10.100
;gpnam3: SMSQ10.100


;cnst17: Factor to compensate for coupling evolution during a pulse
;       (usually +1). A positive factor indicates that coupling
;       evolution continues during the pulse, whereas a negative
;       factor is necessary if the coupling is (partially) refocussed.



;$Id: adeq11etgprdsp,v 1.11.2.2 2015/03/03 11:21:17 ber Exp $
```

Section S3. Pulse program for PDI experiment described in Figure 1C.

```
;adeq_PDI_2.tw
;avance-version (15/02/27)
; 2D-HSQC-1J(CC)-ADEQUATE
;   with refocussing of C chemical shift
;   using sensitivity improvement
;phase sensitive using Echo/Antiecho gradient selection
;with decoupling during acquisition
;using shaped pulses for 180degree pulses on f2 - channel
;
;B. Reif, M. Koeck, R. Kerssebaum, H. Kang, W. Fenical & C. Griesinger
;   J. Magn. Reson. A118, 282-285 (1996).
;M. Koeck, R. Kerssebaum & W. Bermel, Magn. Reson. Chem. 41, 65-69 (2003)
;
;$CLASS=HighRes
;$DIM=2D
;$TYPE=
;$SUBTYPE=
;$COMMENT=


#include <Avance.incl>
#include <Delay.incl>
#include <Grad.incl>


"p2=p1*2"
"d0=3u"
"d11=30m"

"p0=p3*1.333"
"d4=1s/(cnst2*4)"
"d23=1s/(cnst3*4)"
"d24=1s/(cnst2*cnst11)"


"in0=inf1/2"

"in20=in0"

"d20=d23-4u"

"td1=tdmax(td1,d20*2,in20)"
```

```
"DELTA1=p16+d16-p2-d0*2+4u"
"DELTA2=p16+d16+6u"
"DELTA3=d23-d4-p16-d16-4u-p2-d0"
"DELTA4=d4-p14/2-4u"
"DELTA5=d23-p24/2-4u"
"DELTA6=d24-cnst17*p24/2-4u"
"DELTA7=d4-4u"
"DELTA8=d23-d4-p2-p24/2-4u"


1 ze
  d11 pl12:f2
2 d1 do:f2
3 (p1 ph1)
  4u
  DELTA4 pl0:f2
  (center (p2 ph1) (p14:sp3 ph1):f2 )
  4u
  DELTA4 pl2:f2
  (p1 ph2) (p3 ph4):f2
  4u
  DELTA7 pl2:f2
  (p2 ph1)
  4u
  DELTA8 pl0:f2
  (p24:sp7 ph8):f2
  4u
  DELTA5 pl2:f2
  (p1 ph1)(p3 ph9):f2
  d0
  (p2 ph1)
  d0
  DELTA1 pl0:f2 UNBLKGRAD
  (p24:sp7 ph11):f2
  4u
  p16:gp1
  d16 pl2:f2
  (p0 ph10):f2
  4u
  d20 pl0:f2
  (p24:sp7 ph11):f2
  4u
```

```
  p16:gp2
  d16
  DELTA3 pl2:f2
  (p2 ph1)
  d0
  d4
  (center (p1 ph1) (p3 ph5):f2 )
  4u
  DELTA6 pl0:f2
  (center (p2 ph1) (p24:sp7 ph1):f2 )
  4u
  DELTA6 pl2:f2
  (center (p1 ph2) (p3 ph6):f2 )
  4u
  DELTA4 pl0:f2
  (center (p2 ph1) (p14:sp3 ph1):f2 )
  4u
  DELTA4
  (p1 ph1)
  DELTA2
  (p2 ph1)
  3u
  p16:gp3*EA
  d16 pl12:f2
  3u BLKGRAD
  go=2 ph31 cpd2:f2
  d1 do:f2 mc #0 to 2 F1EA(calgrad(EA) & calph(ph6, +180), caldel(d0, +in0) & caldel(d20, -in20))
exit


ph1=0
ph2=1
ph4=0 2
ph5=0 0 2 2
ph6=1 1 3 3
ph7=0
ph8=0
ph9=1 1 1 1 3 3 3 3
ph10=1 1 1 1 1 1 1 1 3 3 3 3 3 3 3 3
ph11=0
ph31=0 2 2 0 2 0 0 2 2 0 0 2 0 2 2 0


;pl0 : 0W
```

;pl1 : f1 channel - power level for pulse (default)
;pl2 : f2 channel - power level for pulse (default)
;pl12: f2 channel - power level for CPD/BB decoupling
;sp3: f2 channel - shaped pulse (180degree inversion)
;spnam3: Crp60,0.5,20.1
;sp7: f2 channel - shaped pulse (180degree refocussing)
;spnam7: Crp60comp.4
;p0 : f2 channel - 120 degree high power pulse
;p1 : f1 channel - 90 degree high power pulse
;p2 : f1 channel - 180 degree high power pulse
;p3 : f2 channel - 90 degree high power pulse
;p14: f2 channel - 180 degree shaped pulse for inversion
;   = 500usec for Crp60,0.5,20.1
;p16: homospoil/gradient pulse
;p24: f2 channel - 180 degree shaped pulse for refocussing
;   = 2msec for Crp60comp.4
;d0 : incremented delay (2D)   [3 usec]
;d1 : relaxation delay; 1-5 * T1
;d4 : 1/4J(CH)
;d11: delay for disk I/O   [30 msec]
;d16: delay for homospoil/gradient recovery
;d20: d23 - 4u
;d23: 1/(4J(CC))
;d24: 1/(4J(CH)) for CH
;   1/(8J(CH)) for all multiplicities
;cnst2 : J(CH) = 127 .. 160 Hz
;cnst3 : J(CC) = 35 .. 55 Hz
;cnst11: for multiplicity selection = 4 for CH, 8 for CHn
;cnst17: = -0.5 for Crp60comp.4
;inf1: 1/SW(C) = 2 * DW(C)
;in0: 1/(2 * SW(C)) = DW(C)
;nd0: 2
;in20: = in0
;ns: 16 * n
;ds: >= 16
;td1: number of experiments
;FnMODE: echo-antiecho
;cpd2: decoupling according to sequence defined by cpdprg2
;pcpd2: f2 channel - 90 degree pulse for decoupling sequence

;for z-only gradients:
;gpz1: +78.5%
;gpz2: +77.6%

;gpz3: -59%

;use gradient files:
;gpnam1: SMSQ10.100
;gpnam2: SMSQ10.100
;gpnam3: SMSQ10.100

;cnst17: Factor to compensate for coupling evolution during a pulse
; (usually +1). A positive factor indicates that coupling
; evolution continues during the pulse, whereas a negative
; factor is necessary if the coupling is (partially) refocussed.

;$Id: adeq11etgprdsp,v 1.11.2.2 2015/03/03 11:21:17 ber Exp $