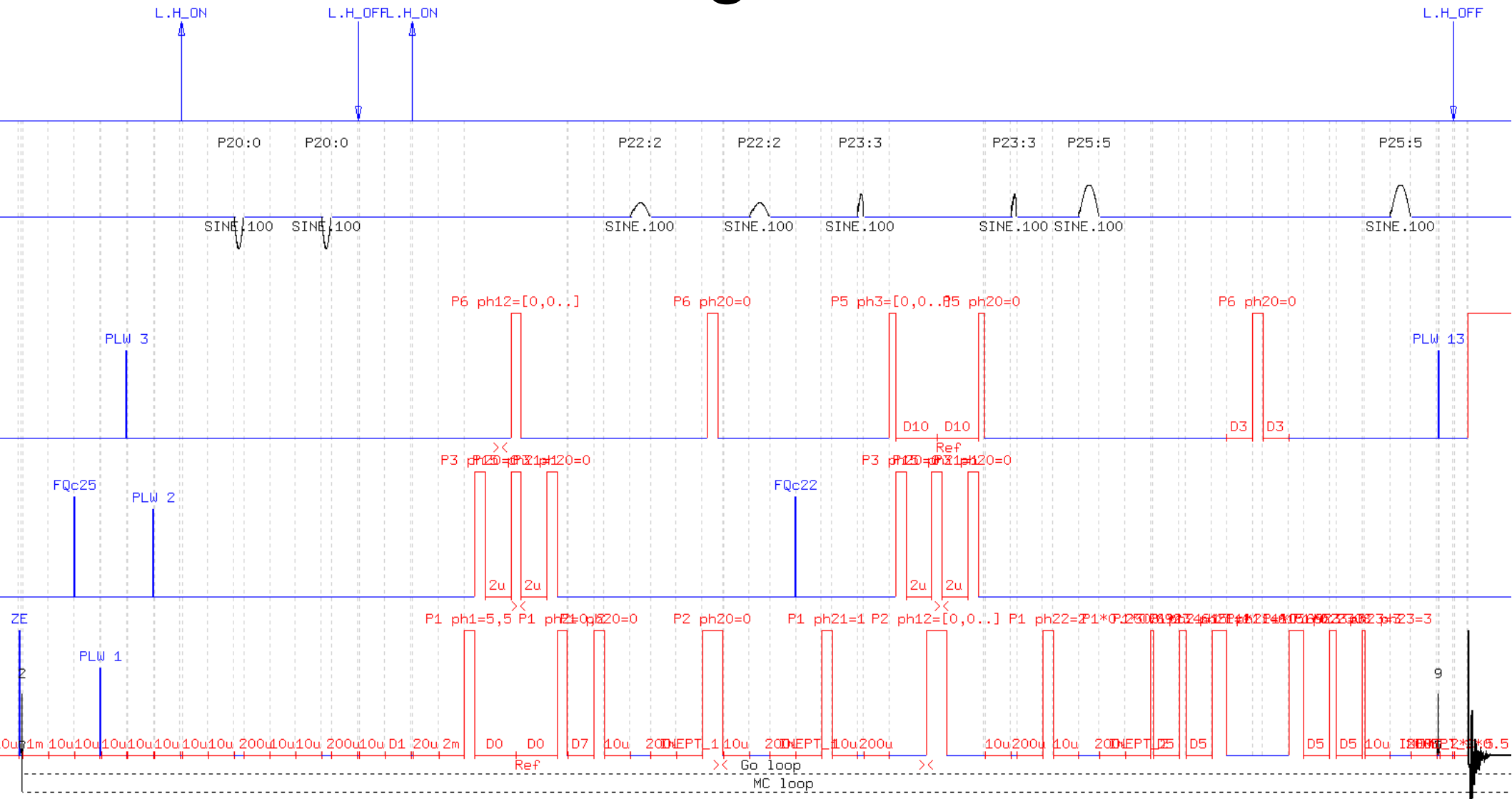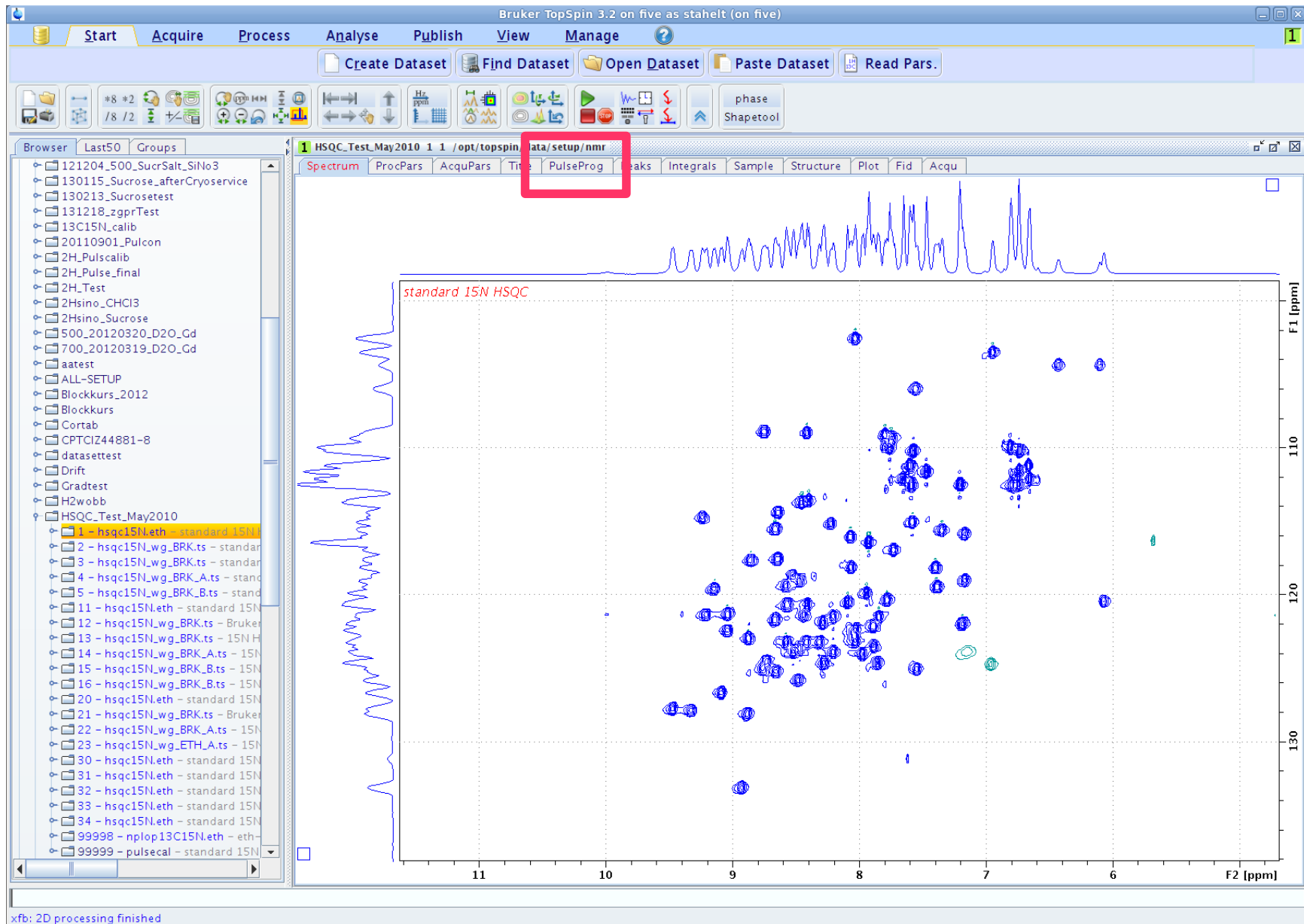# Introduction to Bruker Pulse Programs

Where to find the pulseprogram

- Computer:
  /opt/topspin/exp/stan/nmr/lists/pp/user

  or: **cd $pp** (changes direct to user folder)

- Topspin: edcpul , edpul

- Display: commandline: spdisp

Where to find the pulseprogram

Where to find the pulseprogram

Where to find the pulseprogram

S shows the prcompiled pp

E ←

⊓ or 'spdisp'

A very simple 1D

```
;zg.eth

;1D sequence
```

🟡Header

```
   ze
2 d1 pl1:f1
   p1 ph1
   go=2 ph0
   wr #0
exit
```

🔴Pulse program

```
ph1=0
ph0=0
```

🟣Phase cycles
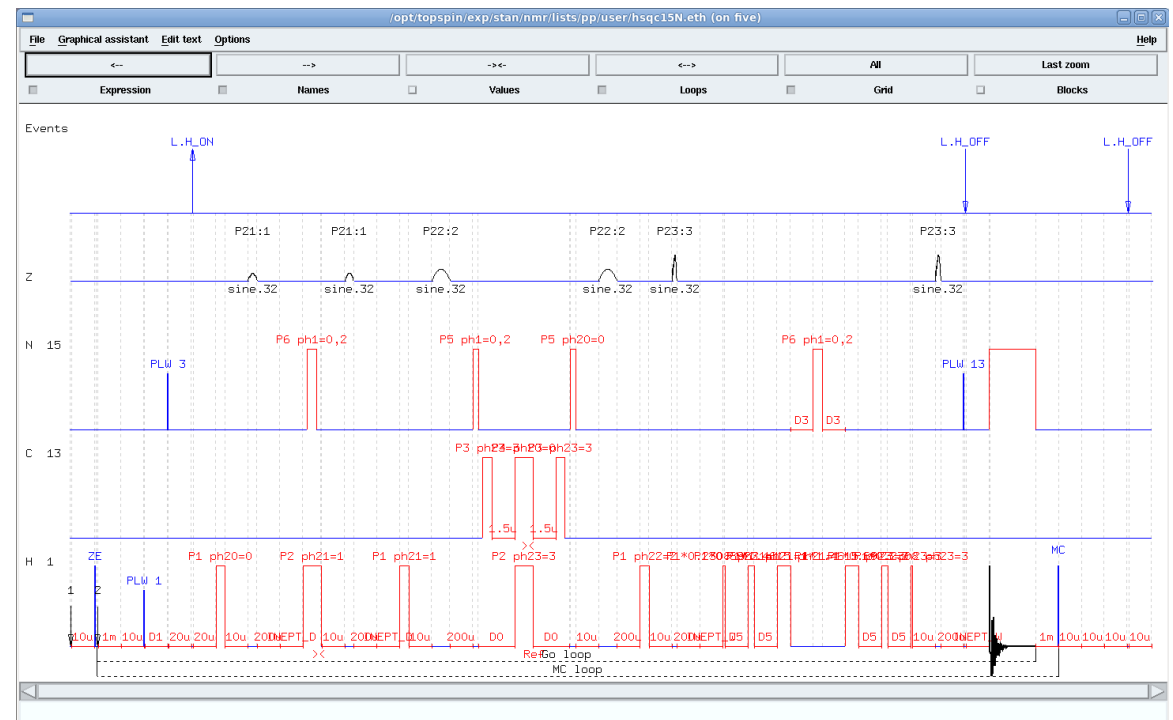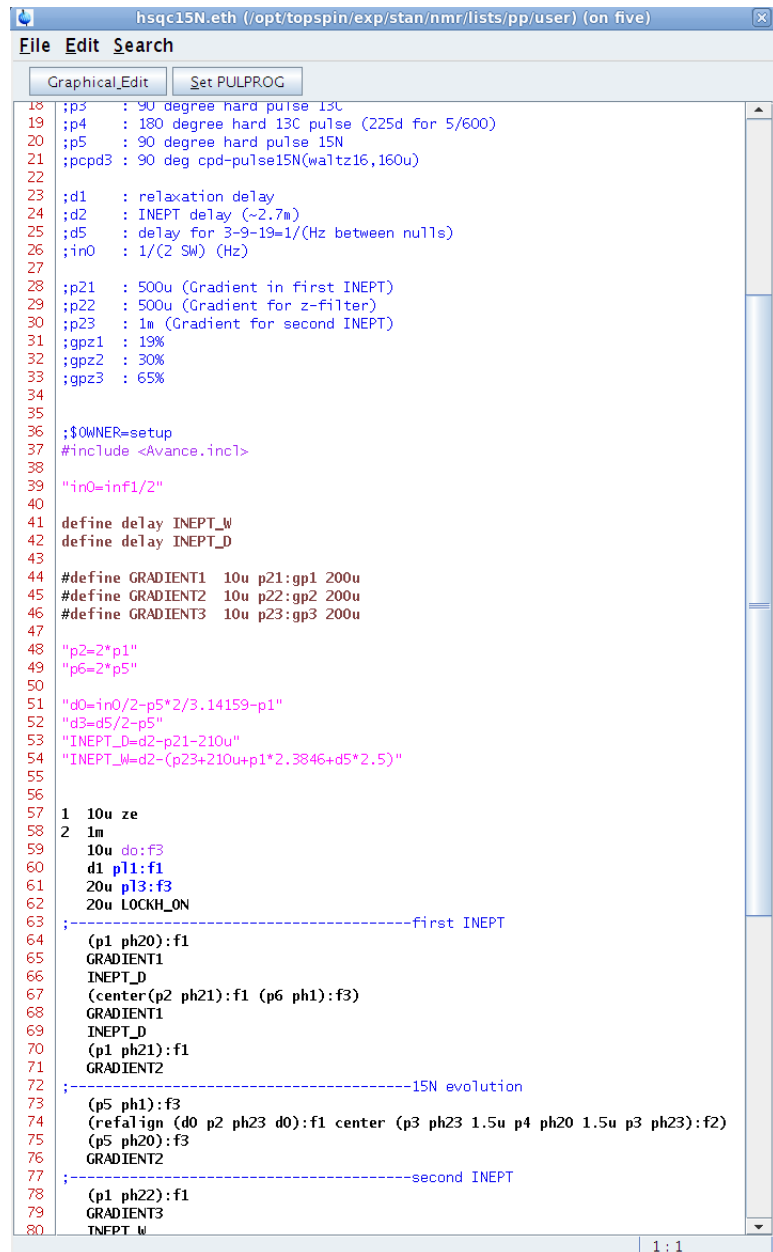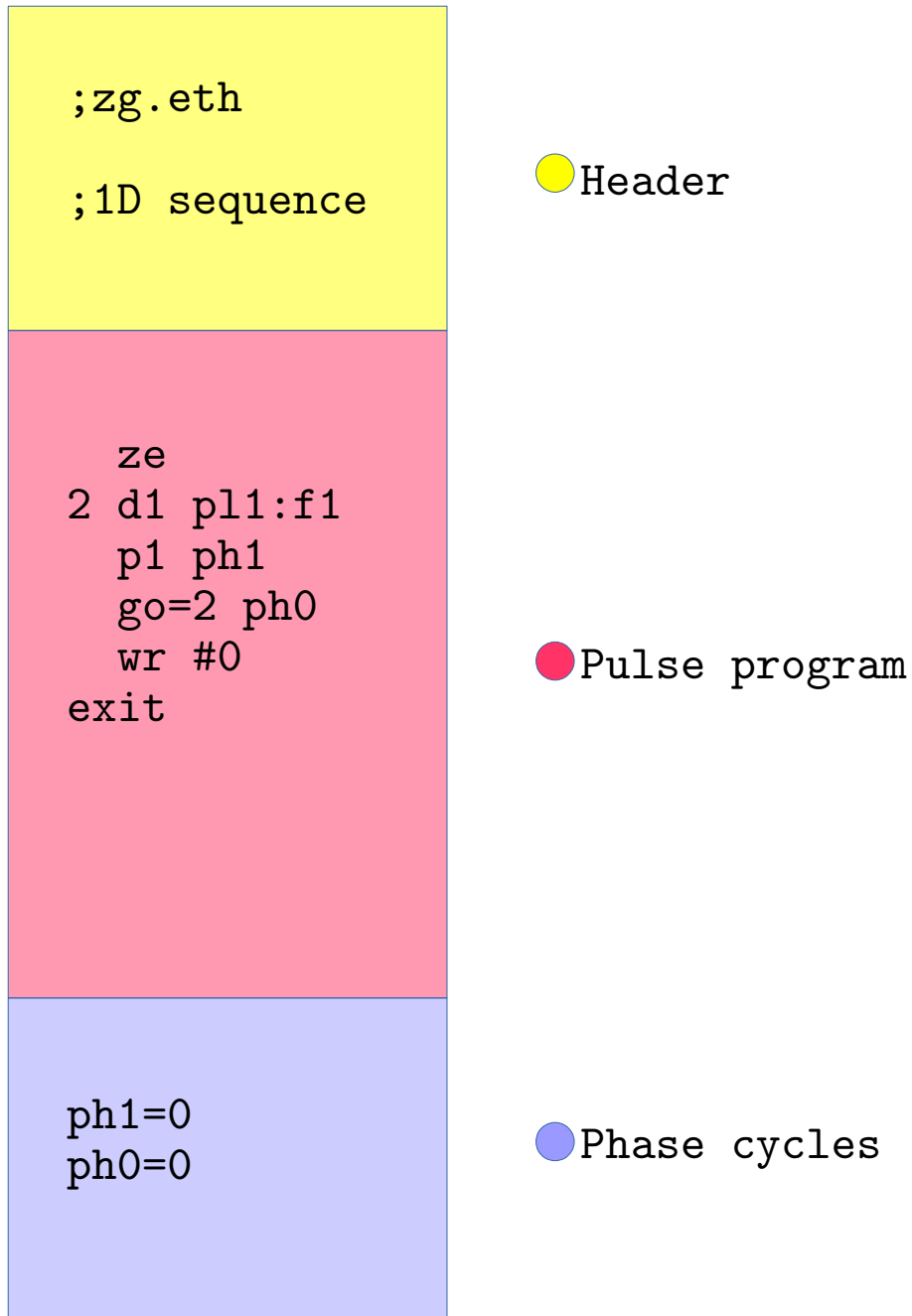
line oriented
➤ each line an action

Starting by zg or gs:

1 executable internal binary form
➤ syntax errors are reported

2 compiled pp is loaded into hardware
➤ measurement begins

```
;zg.eth

;1D sequence


   ze
2 d1 pl1:f1
   p1 ph1
   go=2 ph0
   wr #0
exit




ph1=0
ph0=0
```

Text after semicolon = Comment   **;**

ze   zero (NS; memory), applies DS (`zd` → no DS)

2   label

d1   delay

pl1:f1 powerlevel pl1 on frequency channel f1 (1H)

p1 ph1   pulse p1 with phase ph1 (default: f1))

go=2 ph0 data acqusition, loop to 2 (NS-1 times), phase cycling

➡ phase cycling also used during DS

wr #0   write data to file

➡ data only stored/accessible on disk after all NS scans
    use 'tr' on the command line to store

exit   end of pp

Phase cycles

Pulses & Delays

Pulses

- p0 … p63

- `define pulse p135`
  `define pulse p30d1H`

- manipulate duration:
  `p1*1.5`
  `p3*0.33`

- calculate pulses
  `"p13=p14-d3/2"`

- rectangular pulse power
  - plW0 … plW63
  - set with a delay: `10u pl1`

- shaped pulses
  - `(p1:sp1 ph8):f1`
    `!2u pl1:f1`

Delays

- d0 … d63

- `define delay d135`
- `define delay relax`

- manipulate duration:
  `d2*1.5`
  `d3*0.33`

- calculate delays
  `"d13=3s+aq-dw*10"`

- `3.5u, 10m, 0.1s` → fixed delays

- Incrementing / decrementing delays
  - id1 = d1+ IN[1]
  - dd1 = d1 – IN[1]
  - rd1 resets d1

Comments & Predefinitions

```
;zg.eth

;1D sequence
;d1      : relaxation delay
;pl1     : power for 1H
;p1      : 90 degree hard pulse 1H
```

format for comments on parameters
➤ displayed in ased

```
;$OWNER=setup
```

Ownership

```
#include <Avance.incl>
```

Includes definitions in the file `Avance.incl`, stored in the Bruker pp folder
➤ can add def. in personal file

```
1 ze
2 d1 pl1:f1
  (p1 ph1):f1
  go=2 ph0
  wr #0
exit




ph1=0
ph0=0
```

z-Gradient

```
;zg.eth

;1D sequence
;d1      : relaxation delay
;pl1     : power for 1H
;p1      : 90 degree hard pulse 1H
;p21     : 1 ms (Gradient before acquisition)
;gpz1    : 50 %

;$OWNER=setup

#include <Avance.incl>


1 ze
2 d1
  p21:gp1
  10m pl1:f1
  (p1 ph1):f1
  go=2 ph0
  wr #0
exit



ph1=0
ph0=0
```

suggested gradient length/strength

shaped gradient: defined in file
(eg. `SINE.100`)

Gradient and Auto-shimming

```
;zg.eth

;1D sequence
;d1    : relaxation delay
;pl1   : power for 1H
;p1    : 90 degree hard pulse 1H
;p21   : 1 ms (Gradient before acquisition)
;gpz1  : 50 %

;$OWNER=setup

#include <Avance.incl>



1 ze          ←———— LOCKH_OFF
2 d1            ←——— LOCKH_ON
  p21:gp1
  10m pl1:f1
  (p1 ph1):f1
  go=2 ph0
  wr #0
exit ←———————— LOCKH_OFF
```

LOCKH_OFF and LOCKH_ON
→ defined in Avance.incl

```
ph1=0
ph0=0
```

Gradient and Auto-shimming

```
;zg.eth

;1D sequence
;d1     : relaxation delay
;pl1    : power for 1H
;p1     : 90 degree hard pulse 1H
;p21    : 1 ms (Gradient before acquisition)
;gpz1   : 50 %

;$OWNER=setup

#include <Avance.incl>


1 ze
2 10u LOCKH_OFF
   d1
   10u LOCKH_ON
   p21:gp1
   10m pl1:f1
   (p1 ph1):f1
   go=2 ph0
   wr #0
   10u LOCKH_OFF
exit


ph1=0
ph0=0
```

Define Placeholder: #define

```
;zg.eth

;1D sequence
;d1    : relaxation delay
;pl1   : power for 1H
;p1    : 90 degree hard pulse 1H
;p21   : 1 ms (Gradient before acquisition)
;gpz1  : 50 %

;$OWNER=setup

#include <Avance.incl>

#define GRADIENT1 10u p21:gp1 200u

1 ze
2 10u LOCKH_OFF
  d1
  10u pl1:f1
  10u LOCKH_ON
  GRADIENT1
  (p1 ph1):f1
  go=2 ph0
  wr #0
  10u LOCKH_OFF
exit


ph1=0
ph0=0
```

defines placeholder `GRADIENT1`

Define Parameter: define

```
;zg.eth

;1D sequence
;d1      : relaxation delay
;pl1     : power for 1H
;p1      : 90 degree hard pulse 1H
;p21     : 1 ms (Gradient before acquisition)
;gpz1    : 50 %

;$OWNER=setup

#include <Avance.incl>

#define GRADIENT1 10u p21:gp1 200u
```

```
define pulse proton90
"proton90=p1"
```

defines `proton90` to be a pulse, length = p1

```
1 ze
2 10u LOCKH_OFF
  d1
  10u pl1:f1
  10u LOCKH_ON
  GRADIENT1
  (proton90 ph1):f1
  go=2 ph0
  wr #0
  10u LOCKH_OFF
exit


ph1=0
ph0=0
```

Phase Cycling

```
;zg.eth

;1D sequence
;d1     : relaxation delay
;pl1    : power for 1H
;p1     : 90 degree hard pulse 1H
;p21    : 1 ms (Gradient before acquisition)
;gpz1   : 50 %

;$OWNER=setup

#include <Avance.incl>

#define GRADIENT1 10u p21:gp1 200u

1 ze
2 10u LOCKH_OFF
  d1
  10u pl1:f1
  10u LOCKH_ON
  GRADIENT1
  (p1 ph1):f1
  go=2 ph0
  wr #0
  10u LOCKH_OFF
exit
```

```
ph1=0 1 2 3
ph0=0 1 2 3
```

Phase cycle: select signal / suppress artifacts
0, 1, 2, 3 ➤ 0°, 90°, 180°, 270° (or x, y, -x, -y)

Phase Cycling

- ph0 … ph31

- at the end of the pp

- syntax: ph1= 1 0 0 1 2 3 3 2
     or ph1= 1 0 0 1
                2 3 3 2

- 0➤0° (x), 1➤ 90° (y), 2➤180° (-x), 3 ➤270° (-y)

- next scan next phase

- defined to one channel (p1 ph1):f1

- adding constant to phase (phcor): (p1 ph8:r):f1

- various abbreviations/calculations possible

Water Suppression: Presaturation

```
;zgpr.eth

;1D sequence with presaturation
;d1     : relaxation delay
;pl1    : power for 1H
;p1     : 90 degree hard pulse 1H
;pl9    : power level for presaturation
;p21    : 1 ms (Gradient before acquisition)
;gpz1   : 50 %

;$OWNER=setup

#include <Avance.incl>

#define GRADIENT1 10u p21:gp1 200u

1 ze
2 10u pl9:f1
   10u LOCKH_OFF
   d1 cw:f1
   10u do:f1
   10u pl1:f1
   10u LOCKH_ON
   GRADIENT1
   (p1 ph1):f1
   go=2 ph0
   wr #0
   10u LOCKH_OFF
exit


ph1=0 1 2 3
ph0=0 1 2 3
```

cw ➤ starts "continuous wave" at `pl9`

do ➤ stops cw

Water Suppression: Watergate

```
;zg-wg3919.eth

;1D sequence with watergate using 3-9-19
;d1       : relaxation delay
;pl1      : power for 1H
;p1       : 90 degree hard pulse 1H
;d5       : delay 3-9-19=1/(Hz between nulls)
;p21      : 1000u (Gradient before and after 3-9-19)
;gpz1  : 35%

;$OWNER=setup

#include <Avance.incl>

#define GRADIENT1 10u p21:gp1 200u

1 ze
2 10u LOCKH_OFF
  d1 pl1:f1
  10u LOCKH_ON
  (p1 ph1):f1
  GRADIENT1
  (p1*0.2308 ph3 d5 p1*0.6923 ph3 d5 p1*1.4615 ph3):f1
  d5
  (p1*1.4615 ph4 d5 p1*0.6923 ph4 d5 p1*0.2308 ph4):f1
  GRADIENT1
  go=2 ph0
  wr #0
  10u LOCKH_OFF
exit
```

3-9-19 Watergate segment

```
ph1=0 2
ph0=0 2 2 0
ph3=1 1 2 2 3 3 0 0
ph4=3 3 0 0 1 1 2 2
```

Heteronuclear Decoupling

```
;zg-wg3919-dec.eth

;1D sequence with watergate using 3-9-19 with decoupling
;d1      : relaxation delay
;pl1     : power for 1H
;p1      : 90 degree hard pulse 1H
;pcpd2 : 90 degree for 13C decoupling (~90us)
;pl12    : power level for 13C decoupling
;pcpd3 : 90 degree for 15N decoupling (~180us)
;pl13   : power level for 15N decoupling
;d5      : delay 3-9-19=1/(Hz between nulls)
;p21     : 1000u (Gradient before and after 3-9-19)
;gpz1  : 35%

;$OWNER=setup

#include <Avance.incl>

#define GRADIENT1 10u p21:gp1 200u

1 ze
2 10u
   10u do:f2
   10u do:f3
   10u LOCKH_OFF
   d1 pl1:f1
   10u LOCKH_ON
   10u pl12:f2
   10u pl13:f3
   (p1 ph1):f1
   GRADIENT1
   (p1*0.2308 ph3 d5 p1*0.6923 ph3 d5 p1*1.4615 ph3):f1
   d5
   (p1*1.4615 ph4 d5 p1*0.6923 ph4 d5 p1*0.2308 ph4):f1
   GRADIENT1
   go=2 ph0 cpd2:f2 cpd3:f3
   wr #0
   10u do:f1
   10u do:f2
   10u do:f3
   10u LOCKH_OFF
exit

ph1=0 2
ph0=0 2 2 0
ph3=1 1 2 2 3 3 0 0
ph4=3 3 0 0 1 1 2 2
```

composite **p**ulse **d**ecoupling

cpds1 ...cpds8 ➡ synchronous

cpd1 ...cpd8 ➡ asynchronous

....
  pcpd*3:180
  pcpd :0
  pcpd*2:180
  pcpd*4:0
  pcpd*2:180
....

do stops cpd on given channel

Improve Readability

```
;zg-wg3919-dec.eth

;1D sequence with watergate using 3-9-19 with decoupling
;d1       : relaxation delay
;pl1      : power for 1H
;p1       : 90 degree hard pulse 1H
;pcpd2 : 90 degree for 13C decoupling (~90us)
;pl12     : power level for 13C decoupling
;pcpd3 : 90 degree for 15N decoupling (~180us)
;pl13   : power level for 15N decoupling
;d5       : delay 3-9-19=1/(Hz between nulls)
;p21     : 1000u (Gradient before and after 3-9-19)
;gpz1  : 35%

;$OWNER=setup

#include <Avance.incl>

#define GRADIENT1 10u p21:gp1 200u

1 ze
2 10u
  10u do:f2
  10u do:f3
  10u LOCKH_OFF
  d1 pl1:f1
  10u LOCKH_ON
  10u pl12:f2
  10u pl13:f3
  (p1 ph1):f1
  GRADIENT1
  (p1*0.2308 ph3 d5 p1*0.6923 ph3 d5 p1*1.4615 ph3):f1
  d5
  (p1*1.4615 ph4 d5 p1*0.6923 ph4 d5 p1*0.2308 ph4):f1
  GRADIENT1
  go=2 ph0 cpd2:f2 cpd3:f3
  wr #0
  10u do:f1
  10u do:f2
  10u do:f3
  10u LOCKH_OFF
exit

ph1=0 2
ph0=0 2 2 0
ph3=1 1 2 2 3 3 0 0
ph4=3 3 0 0 1 1 2 2
```

→ DecouplingOFF

→ watergate3919

→ DecouplingON

Improve Readability

```
;zg-wg3919-dec.eth

;1D sequence with watergate using 3-9-19 with decoupling
;d1      : relaxation delay
;pl1     : power for 1H
;p1      : 90 degree hard pulse 1H
;pcpd2 : 90 degree for 13C decoupling (~90us)
;pl12    : power level for 13C decoupling
;pcpd3 : 90 degree for 15N decoupling (~180us)
;pl13   : power level for 15N decoupling
;d5       : delay 3-9-19=1/(Hz between nulls)
;p21     : 1000u (Gradient before and after 3-9-19)
;gpz1  : 35%

;$OWNER=setup

#include <Avance.incl>

#define GRADIENT1 10u p21:gp1 200u

#define DecouplingOFF 10u do:f2 \n 10u do:f3
#define DecouplingON cpd2:f2 cpd3:f3

#define Watergate3919 GRADIENT1 \n (p1*0.2308 ph3 d5 p1*0.6923 ph3 d5 p1*1.4615 ph3):f1 \n d5 \n (p1*1.4615 ph4 d5 p1*0.6923 ph

1 ze
2 10u
  DecouplingOFF
  10u LOCKH_OFF
  d1 pl1:f1
  10u LOCKH_ON
  10u pl12:f2
  10u pl13:f3
  (p1 ph1):f1
  Watergate3919
  go=2 ph0 DecouplingON
  wr #0
  10u do:f1
  DecouplingOFF
  10u LOCKH_OFF
exit

ph1=0 2
ph0=0 2 2 0
ph3=1 1 2 2 3 3 0 0
ph4=3 3 0 0 1 1 2 2
```

Improve Readability

```
;zg-wg3919-dec.eth

;1D sequence with watergate using 3-9-19 with decoupling
;d1      : relaxation delay
;pl1     : power for 1H
;p1      : 90 degree hard pulse 1H
;pcpd2 : 90 degree for 13C decoupling (~90us)
;pl12    : power level for 13C decoupling
;pcpd3 : 90 degree for 15N decoupling (~180us)
;pl13   : power level for 15N decoupling
;d5      : delay 3-9-19=1/(Hz between nulls)
;p21     : 1000u (Gradient before and after 3-9-19)
;gpz1  : 35%

;$OWNER=setup

#include <Avance.incl>
#include "/home/setup/predef.incl"


1 ze
2 10u
  DecouplingOFF
  10u LOCKH_OFF
  d1 pl1:f1
  10u LOCKH_ON
  10u pl12:f2
  10u pl13:f3
  (p1 ph1):f1
  Watergate3919
  go=2 ph0 DecouplingON
  wr #0
  10u do:f1
  DecouplingOFF
  10u LOCKH_OFF
exit

ph1=0 2
ph0=0 2 2 0
ph3=1 1 2 2 3 3 0 0
ph4=3 3 0 0 1 1 2 2
```

```
#define GRADIENT1 10u p21:gp1 200u

#define DecouplingOFF 10u do:f2 \n 10u do:f3
#define DecouplingON cpd2:f2 cpd3:f3

#define Watergate3919 GRADIENT1 \n\
(p1*0.2308 ph3 d5 p1*0.6923 ph3 d5 p1*1.4615 ph3):f1 \n\
d5 \n\
(p1*1.4615 ph4 d5 p1*0.6923 ph4 d5 p1*0.2308 ph4):f1 \n\
 GRADIENT1
```

Improve Readability

```
;zg-wg3919-dec.eth

;1D sequence with watergate using 3-9-19 with decoupling
;d1      : relaxation delay
;pl1     : power for 1H
;p1      : 90 degree hard pulse 1H
;pcpd2 : 90 degree for 13C decoupling (~90us)
;pl12    : power level for 13C decoupling
;pcpd3 : 90 degree for 15N decoupling (~180us)
;pl13   : power level for 15N decoupling
;d5      : delay 3-9-19=1/(Hz between nulls)
;p21     : 1000u (Gradient before and after 3-9-19)
;gpz1  : 35%

;$OWNER=setup

#include <Avance.incl>
#include "/home/setup/predef.incl"


1 ze
2 10u
   DecouplingOFF
   Set_power
   Relax_delay
   Pulse1H
   Watergate3919
   go=2 ph0 DecouplingON
   wr #0
   10u do:f1
   DecouplingOFF
   10u LOCKH_OFF
exit

ph1=0 2
ph0=0 2 2 0
ph3=1 1 2 2 3 3 0 0
ph4=3 3 0 0 1 1 2 2
```

```
#define GRADIENT1 10u p21:gp1 200u

#define DecouplingOFF 10u do:f2 \n 10u do:f3
#define DecouplingON cpd2:f2 cpd3:f3

#define Watergate3919 GRADIENT1 \n\
(p1*0.2308 ph3 d5 p1*0.6923 ph3 d5 p1*1.4615 ph3):f1 \n\
d5 \n\
(p1*1.4615 ph4 d5 p1*0.6923 ph4 d5 p1*0.2308 ph4):f1 \n\
 GRADIENT1




#define Set_power 10u pl12:f2 \n 10u pl13:f3 \n 10u pl1:f1

#define Relax_delay 10u LOCKH_OFF \n d1 \n\
                    10u LOCKH_ON

#define Pulse1H (p1 ph1):f1
```

Questions ?

pp manual:

TopSpin → ? → Manual (docs)

→ Pulse Programming