Pulseq Tutorial Notes

(01_from_FID_to_PRESS)

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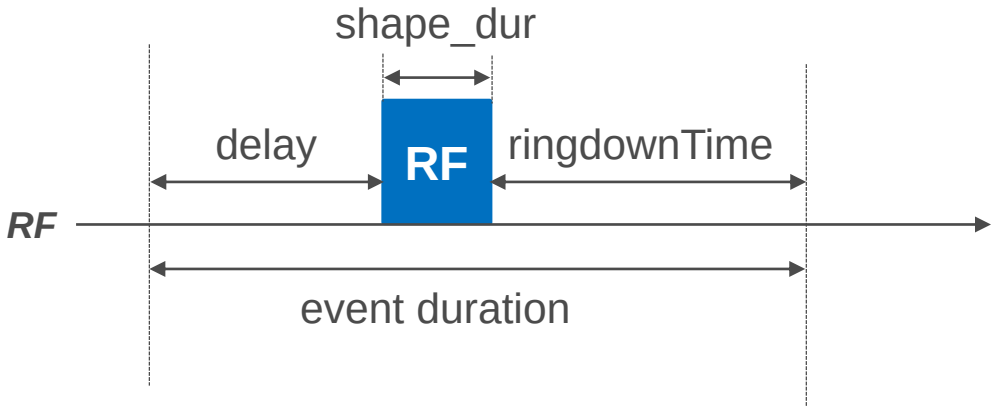
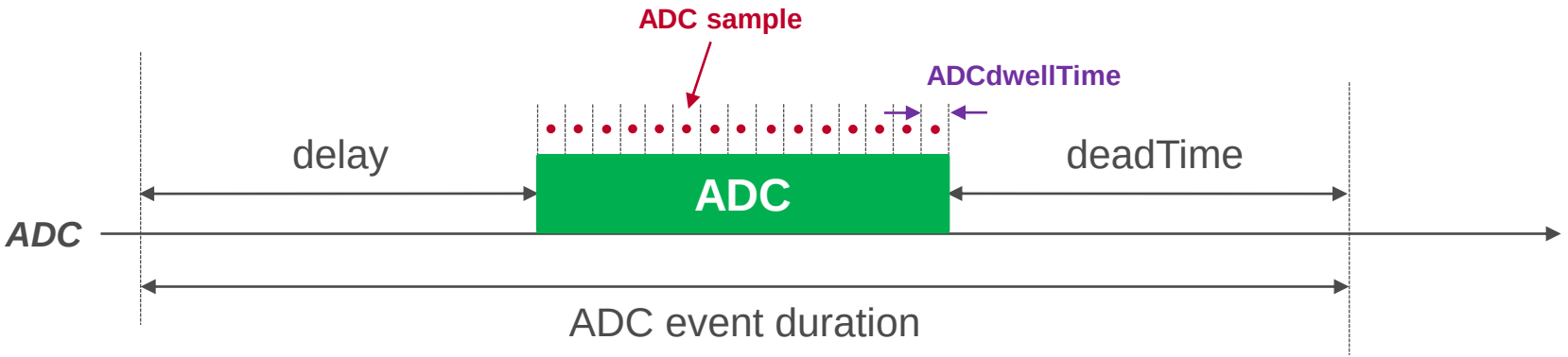
Hard RF pulse – mr.makeBlockPulse()




```
BW=1/(4*Duration)
delay=max(user_desired_delay,deadTime)
event duration=RF_delay+shape_dur+ringdownTime
```

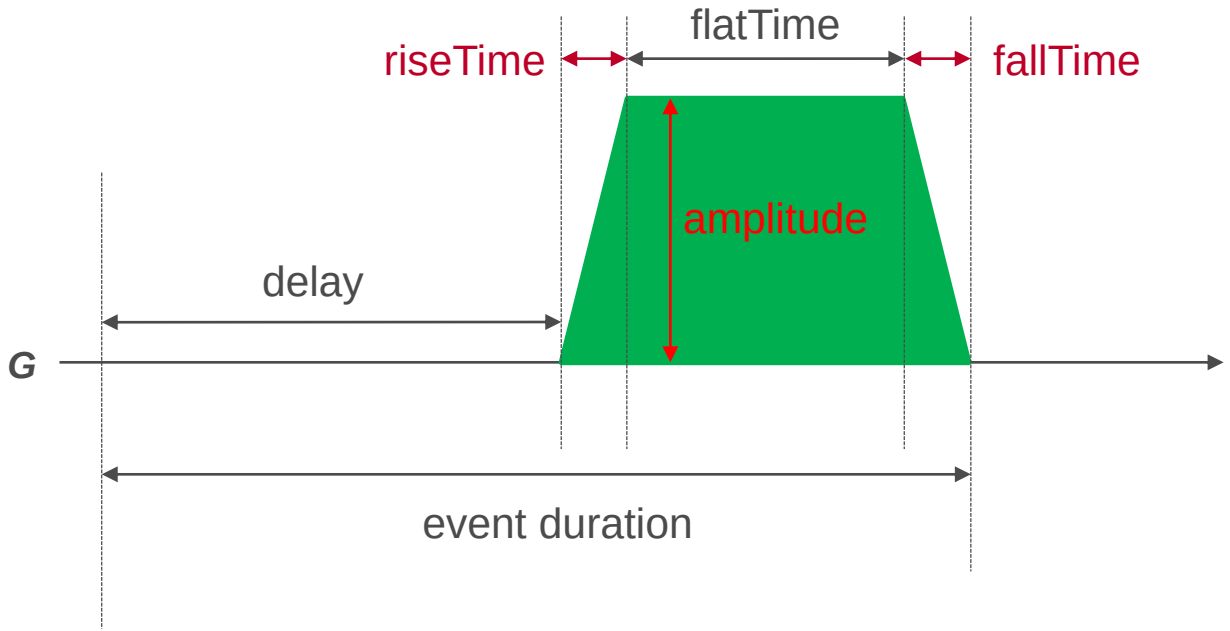
ADC – mr.makeAdc()




```
delay=max(user_defined_delay,deadTime)
event duration=delay+num_sample*ADCdwellTime+deadTime
```

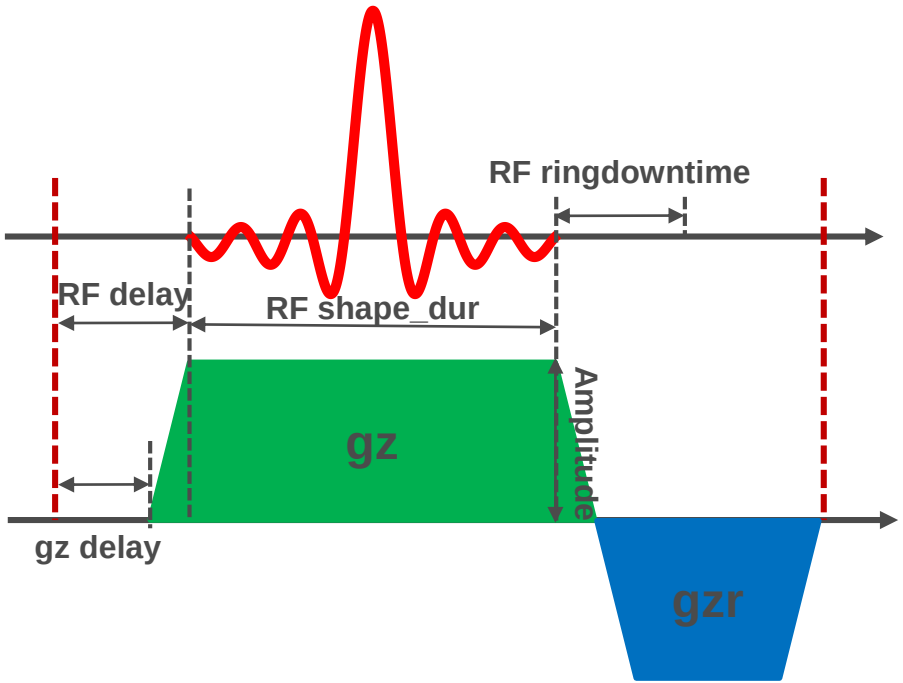
The number of ADC samples (num_sample) on Siemens need to be divisible by 4.
Note that both Pulseq and Siemens define the ADC samples to happen in the centre of the dwell periods.

Trapezoid gradient – mr.makeTrapezoid()



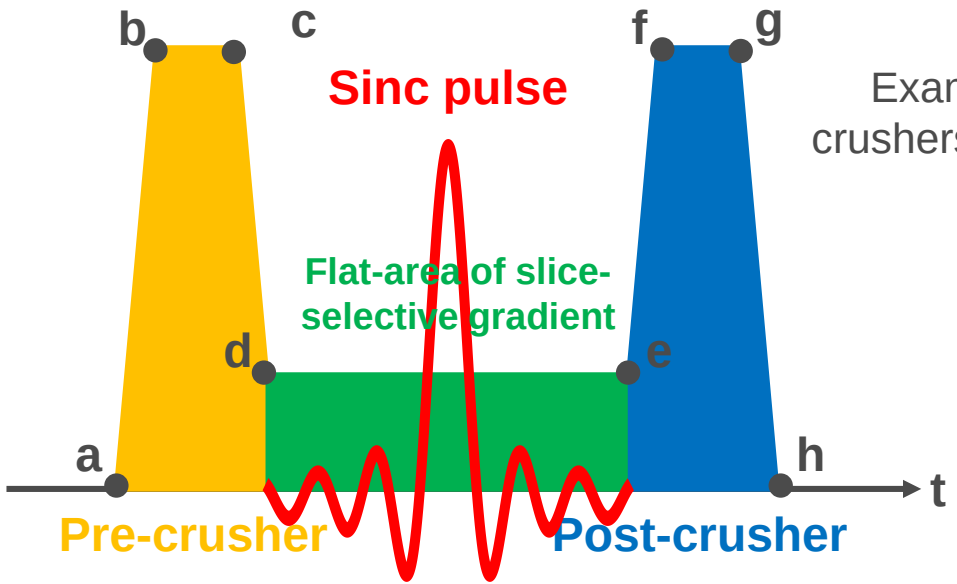

```
grad.area=amplitude*(flatTime+riseTime/2+fallTime/2)
grad.flatArea=amplitude*flatTime
```

Sinc RF pulse – mr.makeSincPulse()




```
BW=timeBwProduct/duration
alpha=apodization
N=round(duration/dwell)
t=(1:N - 0.5)*dwell
tt=t-duration*centerpos
window=(1-alpha+alpha*cos(2*pi*tt/duration))
signal=window*sinc(BW*tt)
flip=sum(signal)*dwell*2*pi
signal=signal*flipAngle/flip
amplitude=BW/sliceThickness
area=amplitude*duration
gz_flatArea=area
gz_flatTime=duration
rf_delay=gz_delay+gz_riseTime
gzr_area=area*(1-centerpos)-0.5*gz_area-area
```

Extended trapezoid gradient – mr.makeExtendedTrapezoid()

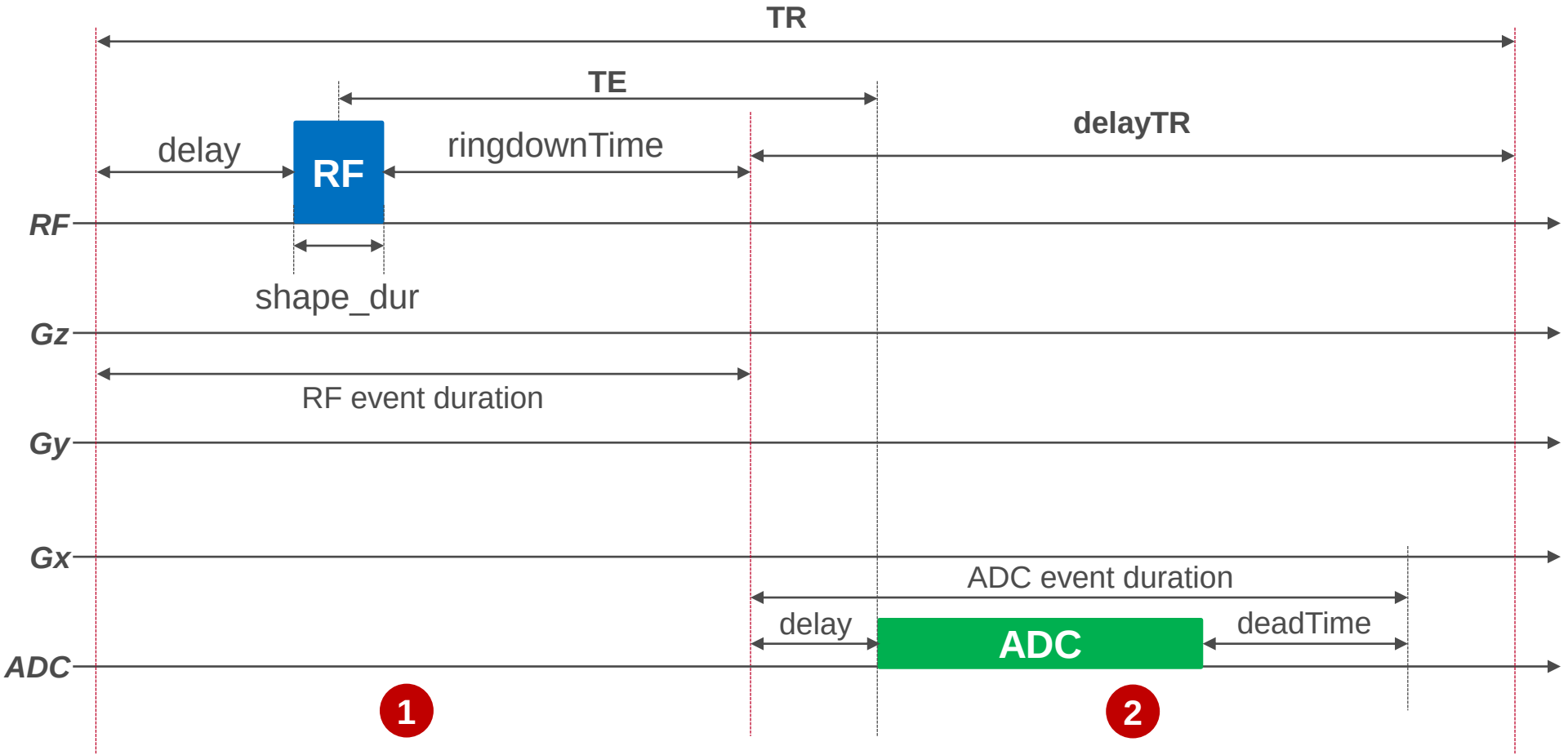


Example: slice-selective gradient with crushers, here composed from 3 gradients:
gradient_1
Amplitudes: [a, b, c, d]
Times: [t_a, t_b, t_c, t_d]
gradient_2
Amplitudes: [d, e]
Times: [t_d, t_e]
gradient_3
Amplitudes: [e, f, g, h]
Times: [t_e, t_f, t_g, t_h]

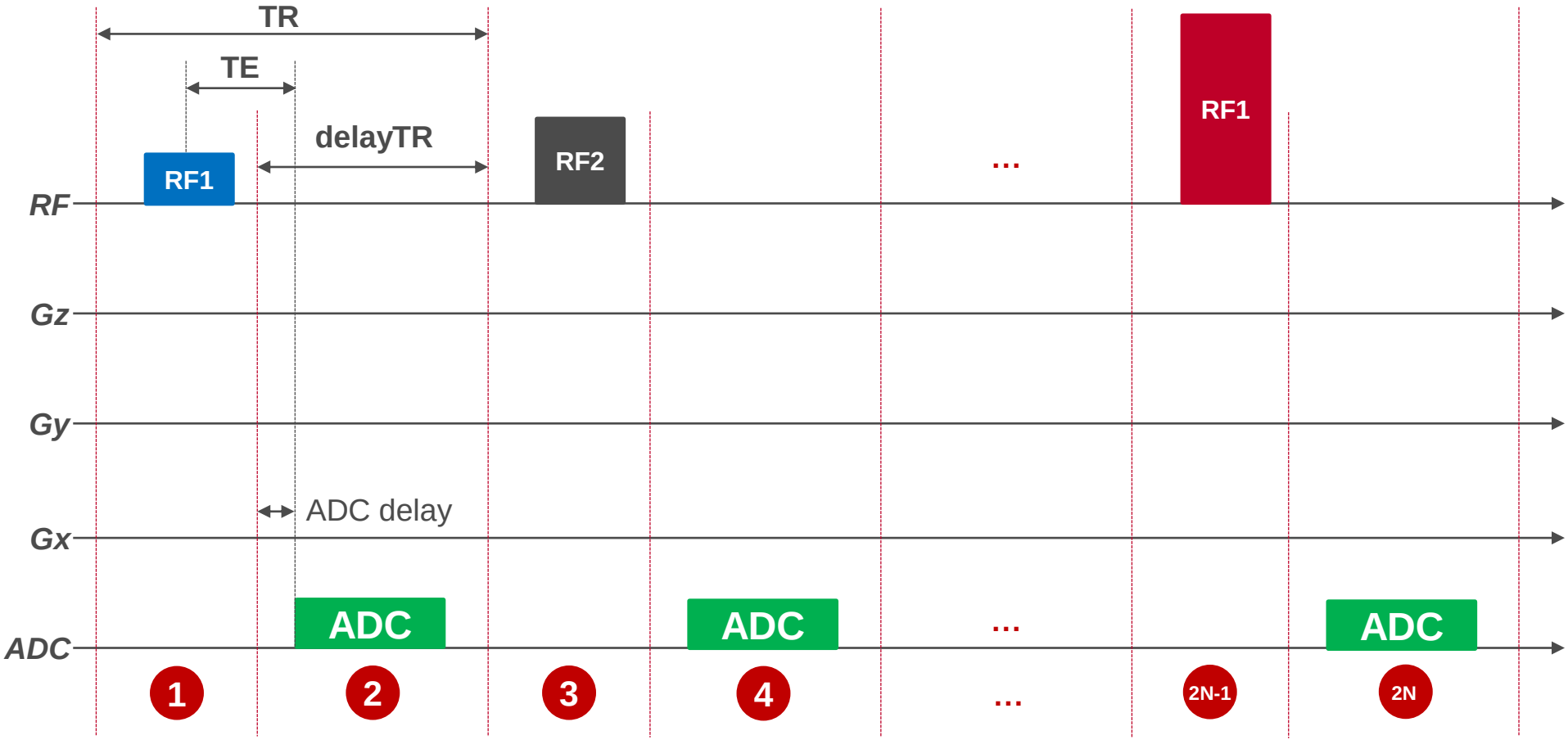
Slice-selective excitation with crushers

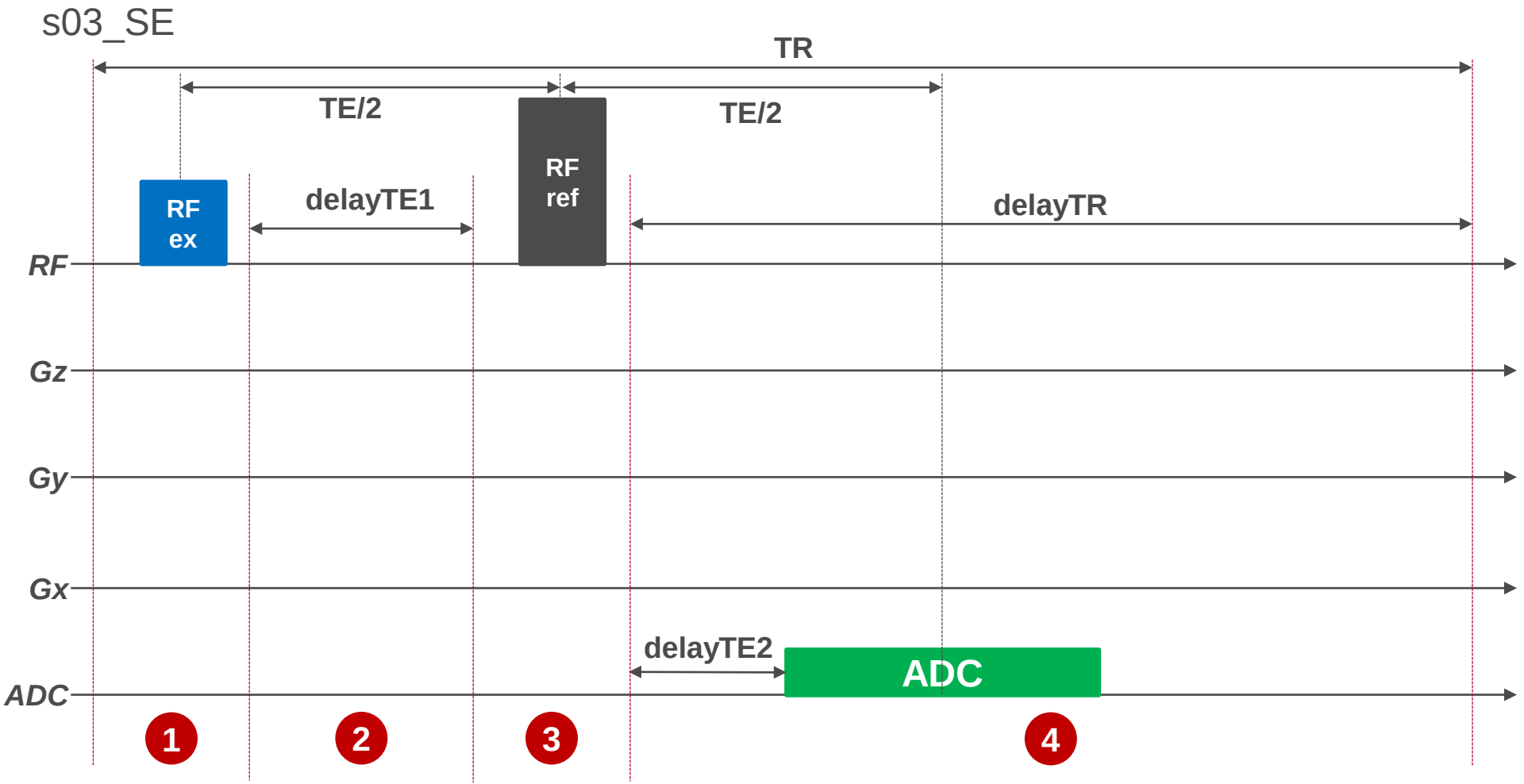
`makeExtendedTrapezoid()` creates an “extended trapezoid” gradient event by specifying a set of points (amplitudes) at specified time points (times) at a given channel with given system limits. The amplitude at the beginning and the end do not have to be 0.

s01_FID (single flip angle)

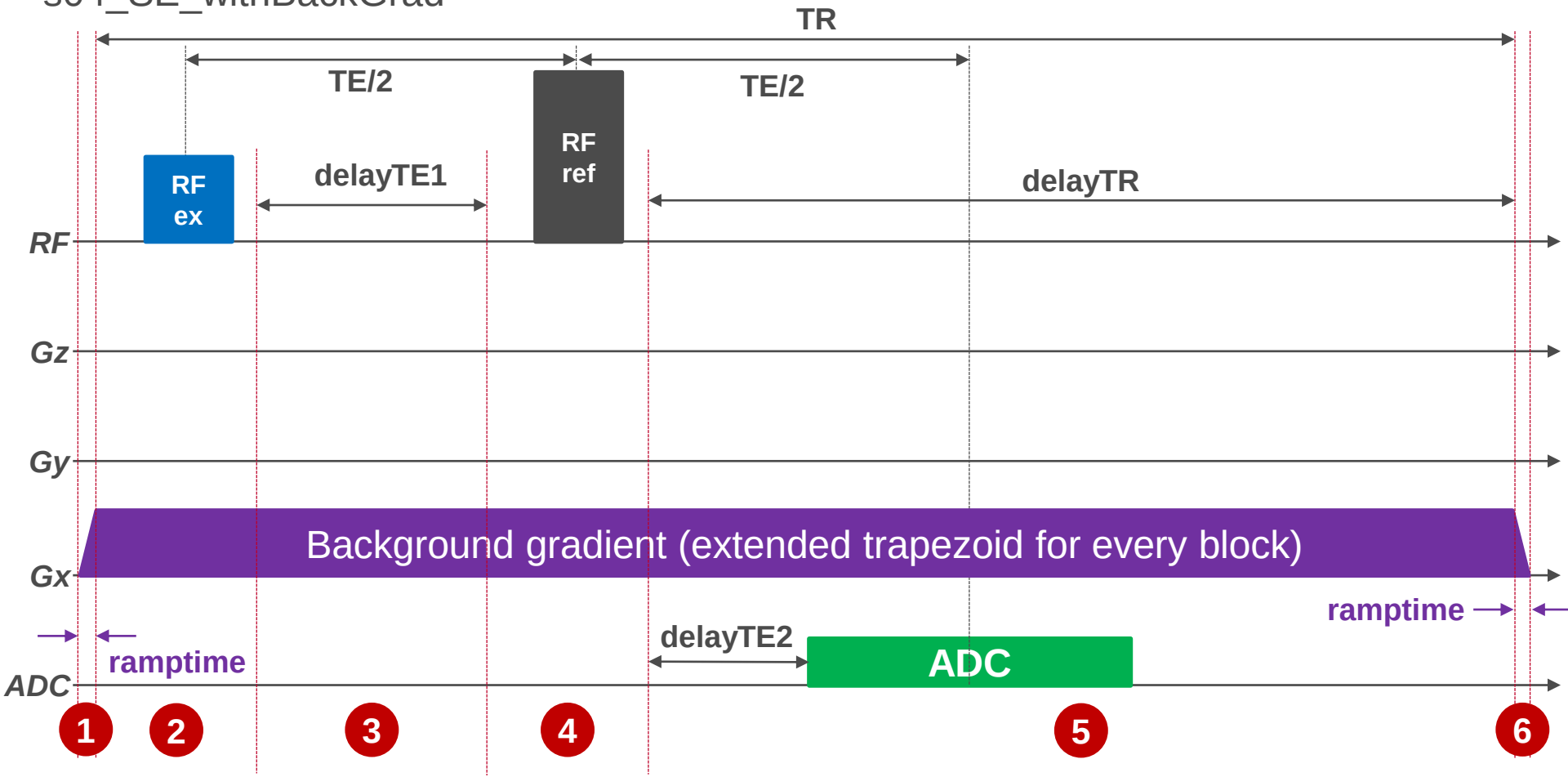


s02_FID_multipleFAs

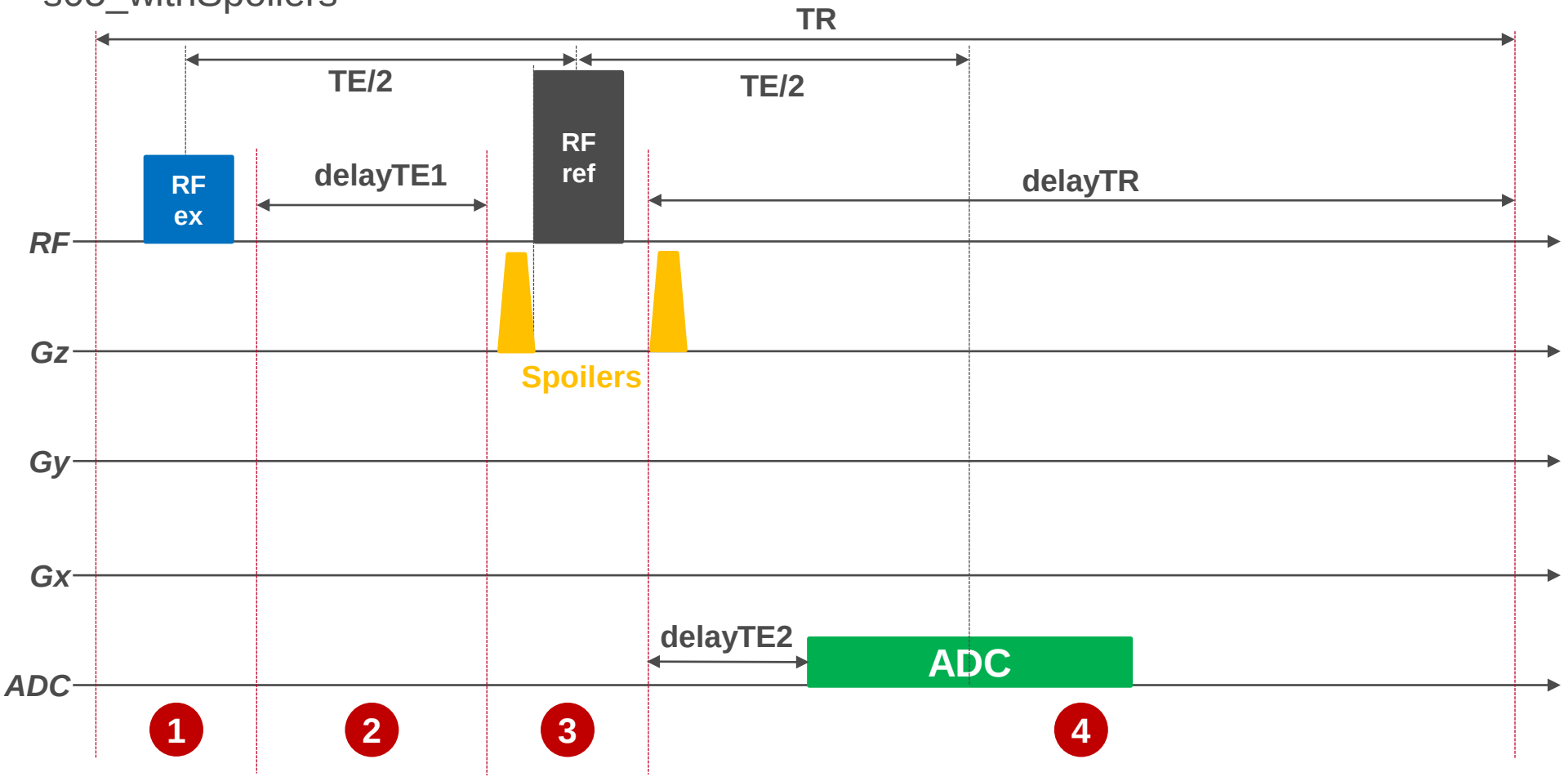


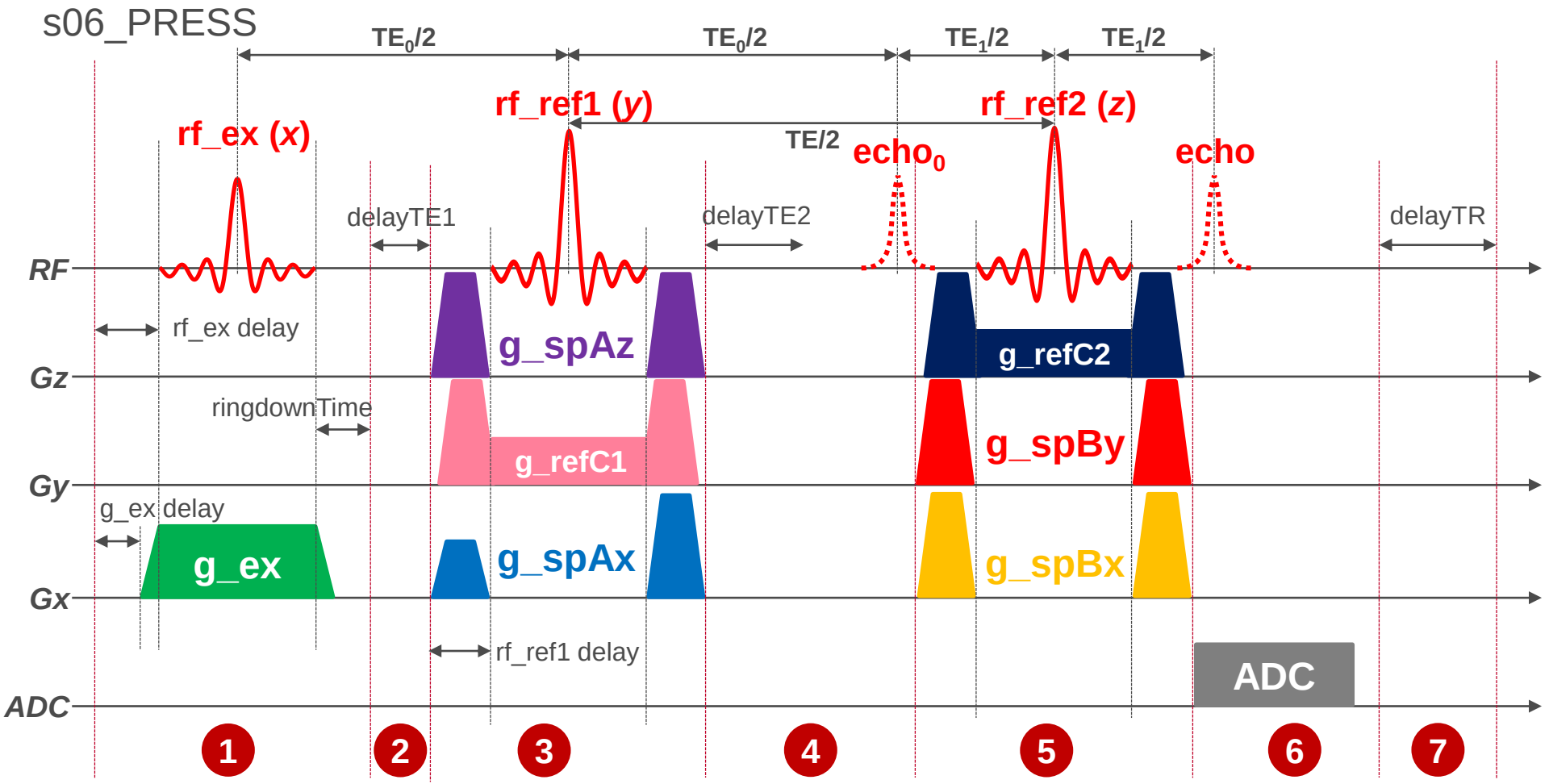

s03_SE
TR
TE/2
TE/2
RF
ex
delayTE1
RF
ref
delayTR
RF
Gz
Gy
Gx
delayTE2
ADC
ADC
1
2
3
4

s04_SE_withBackGrad



s05_withSpoilers




s06_PRESS
TE0/2
TE0/2
TE1/2
TE1/2
rf_ex (x)
rf_ref1 (y)
TE/2
echo0
rf_ref2 (z)
echo
delayTE1
delayTE2
delayTR
RF
rf_ex delay
g_spAz
g_refC2
Gz
ringdownTime
g_refC1
g_spBy
Gy
g_ex delay
g_ex
g_spAx
g_spBx
Gx
rf_ref1 delay
ADC
ADC
1
2
3
4
5
6
7