5.1.

A.

$\gamma B_1 = ((\pi/2)/(2\pi T) = 1/(4T) = 250$ Hz. $\gamma = 4257$ Hz/G $= 42.57$ Hz/μT, therefore $B_1 = (250/42.57) = 5.87$ μT.

B.

$B_0 = 3$ T $= 127.66$ MHz or 127.66×10^6 revolutions per second, therefore in 1 ms there will be 127,660 revolutions.

5.2. $\theta = \gamma B_1 T$, therefore $T = \theta/\gamma B_1 = \pi/(2\pi \times 42.57$ MHz/T $\times 37.6$ μT$) = 312.4$ μs.

5.3.

A.

$R_{90} = 6.08$ and $R_{180} = 12.26$, making the bandwidths 6.08 and 6.13 kHz for 1 and 2 ms pulses, respectively. $G_{90} = 6.08$ kHz/0.2 cm $= 30.4$ kHz/cm and $G_{180} = 6.13$ kHz/0.2 cm $= 30.65$ kHz/cm.

B.

Total positive gradient duration $= 0.5 + 0.15/2 = 0.575$ ms, and amplitude 30.4 kHz/cm. Total negative gradient duration $= 0.15/2 + 0.5 + 0.15/2 = 0.65$ ms. Therefore, negative gradient amplitude $= -(0.575 \times 30.4/0.65) = -26.9$ kHz/cm.

C.

Across the excitation profile where $M_{xy} \geq 0.5M_0$ (i.e. $-9.00 \leq \nu \leq +9.00$ kHz) there exists a circa 500º phase roll due to phase evolution during the 1 ms pulse. This corresponds to a free precession period T of (250º/(360º × 9.00 kHz)) = 0.077 ms (as compared to ~0.5 ms for a linear SLR pulse).

$R_{90} = 18.74$, making the slice gradient strength $= 18.74$ kHz/0.2 cm $= 93.7$ kHz/cm. Total positive gradient duration $= 0.077 + 0.15/2 = 0.152$ ms. Therefore, negative gradient amplitude $= -(0.152 \times 93.7/0.65) = -21.9$ kHz/cm

5.4.A.

$M_z/M_0 = \cos^2\theta\cos2\theta - \sin^2\theta$ where $\theta = \gamma B_1T$ = excitation pulse angle.

B.

Solving $M_z/M_0 = \cos^2\theta\cos2\theta - \sin^2\theta = -0.98$ for θ gives the range 71.6° < θ < 108.4°.

C.

The compensation originates from that fact that the middle pulse $2\theta_{+y}$ rotates any remaining M_z to the opposite side of the transverse plane, giving rise to the cos2θ term as derived under A. Without the middle pulse, the expression would reduce to that for a simple square inversion pulse (i.e. cos2θ).

D.

For a hard pulse the inversion interval is encountered for 84.3° < θ < 95.7°. MLEV is therefore (108.4° – 71.6°)/(95.7° – 84.3°) = 3.22 times less sensitive to error in the nutation angle.

E. The composite WALTZ pulse provides excellent compensation towards off-resonance effects. However, it does not provide any compensation with respect to RF inhomogeneity.

5.5.

A. $\text{SAR} \sim B_{1\text{max}}{}^2.f_{B,\text{average}}{}^2T = B_{1\text{rms}}{}^2T$

Doubling the length T, halves the $B_{1\text{rms}}$, such that the power deposition reduces by 50%.

B.

From Table 5.1 it follows that:

$B_{1\text{rms}}$(sinc, 90) = 1.52 kHz

$B_{1\text{rms}}$(sinc, 180) = 3.04 kHz

B_{1rms}(SLR, 90) = 1.38 kHz
B_{1rms}(SLR, 180) = 3.85 kHz

Relative SAR with sinc pulses : $(1.52)^2 + 2 \times (3.04)^2 = 20.79$
Relative SAR with SLR pulses : $(1.38)^2 + 2 \times (3.85)^2 = 31.55$

The SLR pulses thus increase the SAR by more than 50%.

C.

A 5 ms square 90º pulse requires $B_1 = 50$ Hz. Since the maximum RF amplitude is limited to 1500 Hz only those pulses in Table 5.1 with $B_{1max} < 30$ can be selected. In order to minimize the chemical shift displacement, the bandwidth = R/T much be maximized. Since the shortest pulse length T can be achieved with a pulse that requires the lowest B1max, such that maximizing R/T is synonymous with maximizing R/B_{1max}. When the square pulse is excluded (on grounds of the poor frequency profile), the best pulses for excitation and refocusing are the Gaussian (10% truncation) and regular sinc pulses, respectively. It therefore follows that the optimized RF pulses do not necessarily improved the bandwidth per unit of B_1. Instead they improve the shape of the frequency profile.

D.

The 90º Gaussian pulse can be executed with T = 0.295 ms and $B_{1max} = 1.5$ kHz, while the 180º sinc pulse can be executed with T = 1.9 ms and $B_{1max} = 1.5$ kHz.

The relative SAR of the default pulses is: $(1.52)^2 + (3.04)^2 = 11.552$
The relative SAR of the new, maximum bandwidth pulses is:
$(2.0/0.295)(1.00)^2 + (2.0/1.9)(3.04)^2 = 16.508$

E.

Reducing the echo-time does not change the SAR. Increasing the TR by a factor of 2 decreases the SAR by a factor of 2.

5.6.

A.

The reduction in length and the increase in nutation angle both increase the RF amplitude requirements by a factor of 2. Therefore, depending on whether the amplifier setting is implemented as an attenuator or amplifier, the power setting should be 23 – 12 dB = 11 dB or 23 + 12 dB = 35 dB.

B.

Using Table 5.1, a 1 ms 90 sinc pulse require B_{1max} = 1425 Hz. The power setting for this pulse must therefore be set to 10 ± $20\log_{10}(1310/1425)$ = 10 ± 0.73 dB, depending on the mode of the amplifier.

5.7. A 10 ms AFP pulse with R = 60 has a bandwidth of 6.0 kHz.

A. At an offset of +30 kHz the magnetization tilts away from the +z axis during the pulse, after which it will return to the +z axis at the end of the pulse. In the presence of T2 relaxation, part of the magnetization may disappear during the pulse so that not all magnetization return to the +z axis.

B. At a frequency offset of +3 kHz the frequency modulation of the pulse can be seen as running from +6 kHz to 0 kHz. This means that at the end of the AFP the magnetization is excited, rather than inverted.

C. At a frequency offset of +0.3 kHz the magnetization inverts to the –z axis. In the presence of T_1 relaxation the inversion will be incomplete.

D. At a frequency offset of –3 kHz the frequency modulation of the pulse can be seen as running from 0 kHz to –6 kHz. At the point the magnetization also is excited.

E. The features under B and D can be used for frequency selective excitation, for example in water suppression. The features in A and C, i.e. frequency-selective inversion has numerous application ranging from spatial localization to spectral editing. None of the features A-D are present during a AFP pulse based on tanh/tan modulation, since the frequency profile of this pulse is dependent on the B_1 amplitude.

5.8. Consider a 16.02 ms optimized SLR 90º pulse (R = 6.0), segmented into 81 RF pulses of 20 μs each interleaved with 180 μs delays.

A.

The width of the center band of any DANTE sequence is simply given by R/T, where T is the duration of the entire pulse. Therefore, the bandwidth of the center band equals 6/16.02 = 374.5 Hz.

B.

Adjacent excitation bands will appear at n/(20 μs + 180 μs) = n. 5.0 kHz (n = 1, 2, 3…).

C.

Relative SAR conventional pulse = 16.02 $(B_1)^2$

Relative SAR DANTE pulse = 1.62 $(B_1\ 16.02/1.62)^2 = 158.4\ (B_1)^2$

D. Equal separation between the excitation bands means that the sum of one pulse segment and one delay much remain constant at 200 μs. Halving the excitation band means that the pulse length must be doubled. The new pulse therefore consists of 161 pulse segments of 20 μs interleaved with 160 delays of 180 μs each. (This brings the pulse to within 0.1% of the requested parameters).

5.9. A PRESS sequence is executed with 3 ms optimized SLR90 (R = 12) and SLR180 (R = 12) excitation and refocusing pulses, respectively. Signal is acquired from a 2 × 2 × 2 cm = 8 mL volume in the human occipital cortex with TR = 1500 ms and TE = 20 ms.

A.

A 3 ms SLR90 (R = 12) pulse has a 4.0 kHz bandwidth. The required gradient strength to select a 2 cm volume is then equal to 2.0 kHz/cm. The amplitude of the refocusing gradient can then be calculating as:

$$G_{\text{refocusing}} = -2.0\times(3000/2 + 500/2)/(500/2 + 1000 + 500/2) = -2.33 \text{ kHz /cm}$$

The first factor of 2 in 3000/2 comes from the fact that only half of the pulse length needs to be refocused. The other factors of 2 come from the fact that gradient ramps equal half the area of full amplitude gradients.

B.

With a constant-slope gradient, the ramp times with become dependent on the gradient amplitude. If GR is the gradient ramping rate (in kHz/cm/ms), then the gradient ramp duration, t, to a gradient amplitude G is equal to G/GR. For slice selection and refocusing gradient amplitudes GSS and GSSR, pulse length T and gradient refocusing plateau duration T_{plateau}, the gradient areas are equal when:

$$\left(\frac{\mathrm{T}}{2}+\frac{\mathrm{GSS}}{\mathrm{GR}}\right)\mathrm{GSS}+\left(\frac{\mathrm{GSSR}}{\mathrm{GR}}+\mathrm{T}_{\text{plateau}}\right)\mathrm{GSSR}=0$$

which gives GSSR = –3.47 kHz/cm.

C.

With an effective dephasing pulse length of T/10, GSSR now becomes –0.733 kHz/cm for both modes of gradient operation.