Lecture 2: Advanced RF Pulse Design – Tagging Pulses

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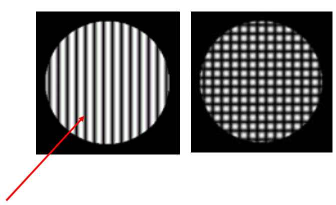
Review

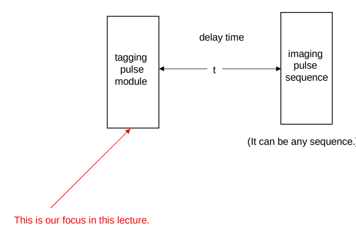
- What is the equation that governs the interaction between magnetization and an RF pulse?
- What is the relationship between the flip angle of an RF pulse and the B1-field?
- Name a pulse shape commonly used to select a specific frequency band.
- What are the three commonly used functions of RF pulses?
- What are the typical flip angles for excitation, refocusing, and inversion pulses, respectively?

Tagging Pulses (pages 164-176)

- What is a tagging pulse?



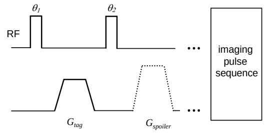
Tagging Pulses as a Module in a Pulse Sequence



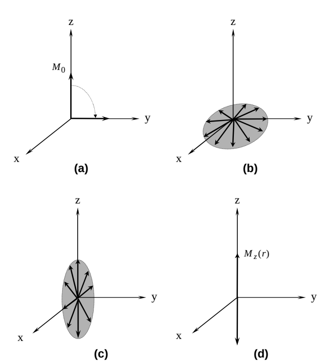
SPAMM Technique

(Spatial Modulation of Magnetization)

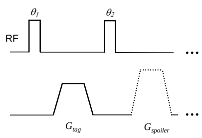
Axel and Dougherty, Radiology, 1989



Assume θ1= -θ2 = 90º



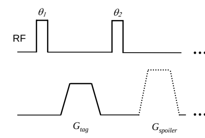
SPAMM Quantitative Description



Immediately after the 1st pulse:

$$\begin{bmatrix} M_x \\ M_y \\ M_z \end{bmatrix} = M_0 \begin{bmatrix} 0 \\ \sin\theta_1 \\ \cos\theta_1 \end{bmatrix}$$

SPAMM Quantitative Description



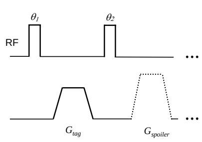
With the tagging gradient:

$$\phi(r) = \gamma r \int_0^T G_{tag}\, dt$$

At the end of the tagging gradient:

$$\begin{bmatrix} M_x(r) \\ M_y(r) \\ M_z \end{bmatrix} = M_0 \begin{bmatrix} \sin\theta_1 \sin\phi(r) \\ \sin\theta_1 \cos\phi(r) \\ \cos\theta_1 \end{bmatrix}$$

SPAMM Quantitative Description



After the second pulse:

$$\begin{bmatrix} M_x(r) \\ M_y(r) \\ M_z(r) \end{bmatrix} = M_0 \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\theta_2 & \sin\theta_2 \\ 0 & -\sin\theta_2 & \cos\theta_2 \end{bmatrix} \begin{bmatrix} \sin\theta_1 \sin\phi(r) \\ \sin\theta_1 \cos\phi(r) \\ \cos\theta_1 \end{bmatrix}$$

$$M_z(r) = -M_0 \left[\sin\theta_1 \sin\theta_2 \cos\phi(r) - \cos\theta_1 \cos\theta_2\right]$$

With the spoiler gradient:

$$M_z(r) = -M_0 \left[\sin\theta_1 \sin\theta_2 \cos\phi(r) - \cos\theta_1 \cos\theta_2\right]$$

$$M_x(r) = M_x(r) = 0$$

Period of the Tags

$$\lambda = \frac{2\pi}{\gamma \int_0^T G_{tag}\, dt}$$

In a magnitude image, if θ1= -θ2 = 90º, what is the actual period? $|M_z(r)| = M_0 |\cos\phi(r)|$

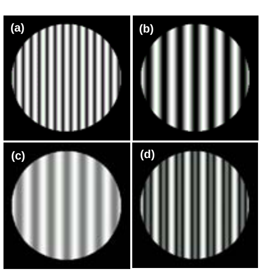
bright $r = n\lambda/2 \quad (n = 0, \pm 1, \pm 2, ...)$

dark $r = (n/2 + 1/4)\lambda$

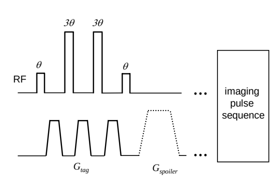
What will happen if $\theta_1 = \theta_2 = 45^\circ$

$$Mz = \frac{M_0}{2}\left[1 - \cos\phi(r)\right]$$

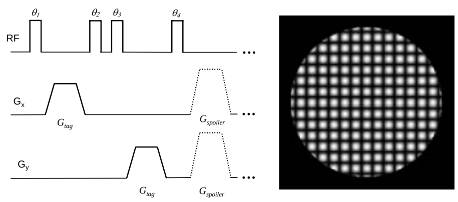
So the actual period also depends on the flip angles.



Variations of Tagging Pulses



2D Tagging Pulses

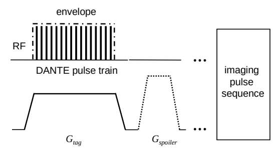


(a) (b)

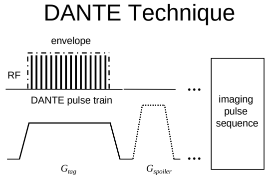
DANTE Technique

(Delayed Alternating with Nutation for Tailored Excitation)

Morris and Freeman, 1978
Mosher and Smith, 1990



DANTE Technique



B1-field

$$B_1(t) = A(t,T) \sum_{n=-\infty}^{\infty} \delta(t - n\tau)$$

Excited magnetization

$$M(f) = \int_{-\infty}^{\infty} B_1(t) e^{-i2\pi ft} dt = W(f,F) \otimes \sum_{N=-\infty}^{\infty} \delta(f - N\Delta f)$$

DANTE Technique

Frequency separation of the replica:

$$\Delta f = \frac{1}{\tau}$$

Spatial separation of the replica in the presence of a tagging gradient

$$r = \frac{2\pi f}{\gamma G_{tag}}, \qquad \Delta r = \frac{2\pi \Delta f}{\gamma G_{tag}}$$

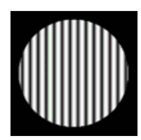


Table 5.5.1 Relationship between $A(t,T)$ and $W(f,F)$

Function	$A(t,T)$	$W(f,F)$
Gaussian	$Ce^{-\frac{t^2}{2T^2}}$	$C'e^{-\frac{f^2}{2F^2}}$
RECT	$C\,\mathrm{RECT}\left(\frac{t}{T}\right)$	$C'\,\mathrm{SINC}\left(\frac{f}{F}\right)$
SINC	$C\,\mathrm{SINC}\left(\frac{t}{T}\right)$	$C'\,\mathrm{RECT}\left(\frac{f}{F}\right)$

* C and C' are constants with units of micro-Tesla.

2D DANTE Technique