Introdução básica à instrumentação em RMN

Prof. Dr. Marcos de Oliveira Junior

Conteúdo

- Arquitetura básica de um espectrômetro de RMN
- Componentes eletrônicos de rádio frequência
- Transmissores
- Receptores
- Sonda de RMN
- Campo magnético

•Shimming, l/4, recepção em quadratura, sintonia, etc...

Nuclear spin and magnetic moment

$$\vec{\boldsymbol{\mu}} = \gamma\hbar\vec{\boldsymbol{I}}$$

Magnetic moment

Spin operator

$$\vec{B}_0 = B_0\hat{z}$$

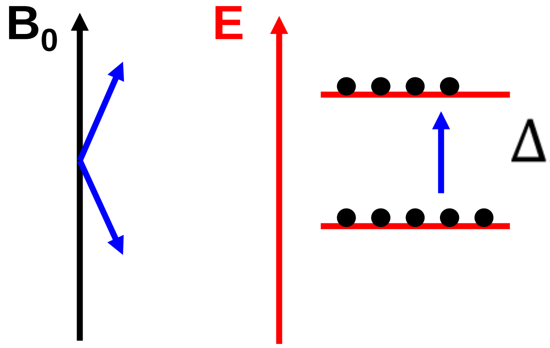
$$\mathcal{H} = -\vec{\boldsymbol{\mu}}\cdot\vec{B}_0 = \gamma\hbar B_0\boldsymbol{I}_z$$

$$\boxed{\mathcal{H} = \omega_0\boldsymbol{I}_z}$$

$$\boldsymbol{I}_z|\varphi\rangle = m|\varphi\rangle, m = -I, -I+1, \ldots, I-1, I$$

Spin ½:

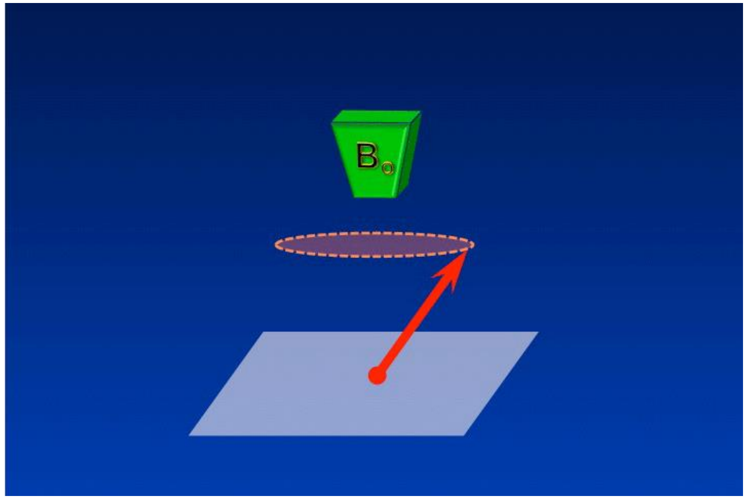
$$\hat{H}_z = \frac{1}{2}\begin{array}{cc} \begin{array}{cc}\langle\alpha| & \quad\langle\beta|\end{array} & \\ \begin{pmatrix}\omega_0 & 0\\ 0 & -\omega_0\end{pmatrix} & \begin{array}{c}|\beta\rangle\\ |\alpha\rangle\end{array}\end{array}$$



$$\Delta E = \omega_0 = \gamma\hbar B_0$$

Larmor frequency

Conj unto de spins - Magnetização



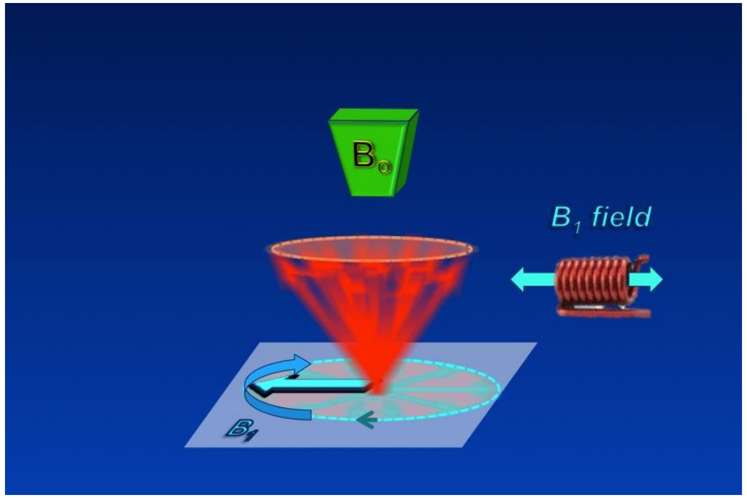
http://mriquestions.com/rotating-frame.html

$$\vec{B_0} = B_0\hat{z} \longrightarrow \frac{d\vec{M}}{dt} = \gamma B_0 \vec{M} \times \hat{z}$$

$$\omega_0 = -\gamma B_0$$

Freq. Larmor

Campos oscilantes



http://mriquestions.com/rotating-frame.html

$$\overrightarrow{B_1}(t) = \mathrm{B}_1\cos(\Omega t)\hat{x}$$

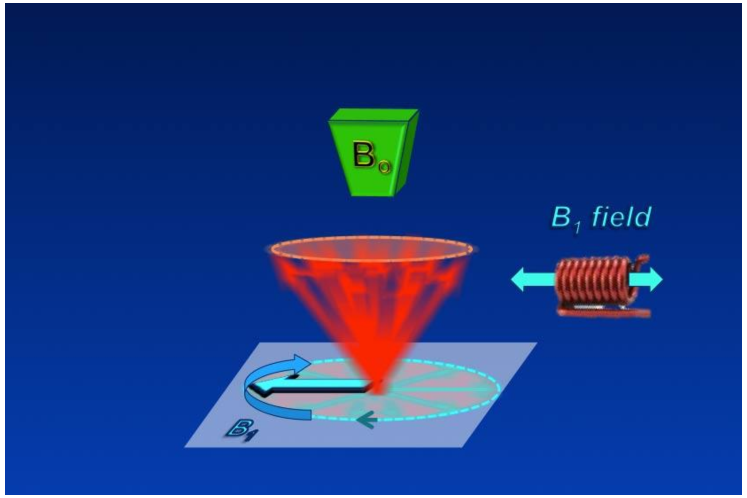
$$\frac{d\vec{M}}{dt} = \gamma B_0\vec{M} \times \hat{z} + \gamma B_1(t)\vec{M} \times \hat{x}$$

The rotating reference frame

$$\frac{d\vec{M}}{dt} = \gamma \vec{M} \times \vec{B_0} \xrightarrow{\vec{B_0} = B_0\hat{z}} \frac{d\vec{M}}{dt} = \gamma B_0 \vec{M} \times \hat{z}$$

$$\omega_0 = -\gamma B_0$$

Freq. Larmor



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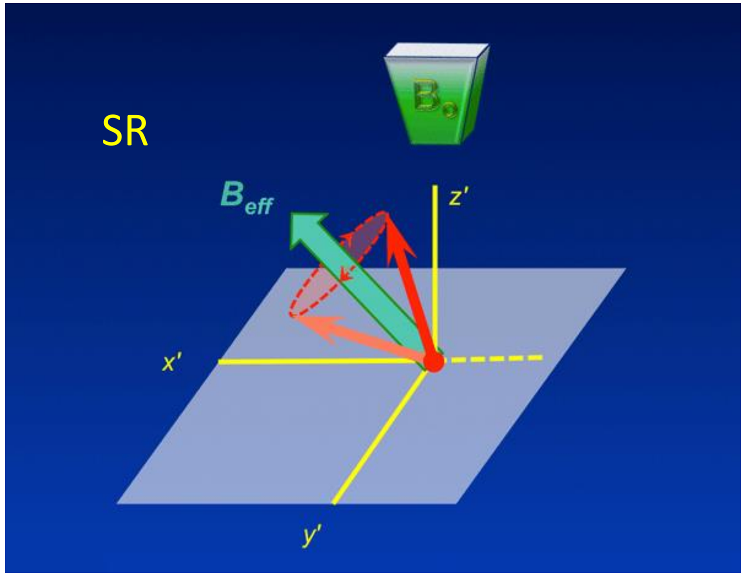
$$\vec{B_1}(t) = \mathrm{B}_1 \cos(\Omega t)\hat{x}$$

$$\frac{d\vec{M}}{dt} = \gamma B_0 \vec{M} \times \hat{z} + \gamma B_1(t) \vec{M} \times \hat{x}$$

Rotating frame: $\Omega_{SR} = \Omega$

$$\frac{d\vec{M}^{SR}}{dt} = (\gamma B_0 + \Omega)\vec{M}^{SR} \times \hat{z}' + \gamma B_1 \vec{M}^{SR} \times \hat{x}'$$

Effective field in the rotating frame



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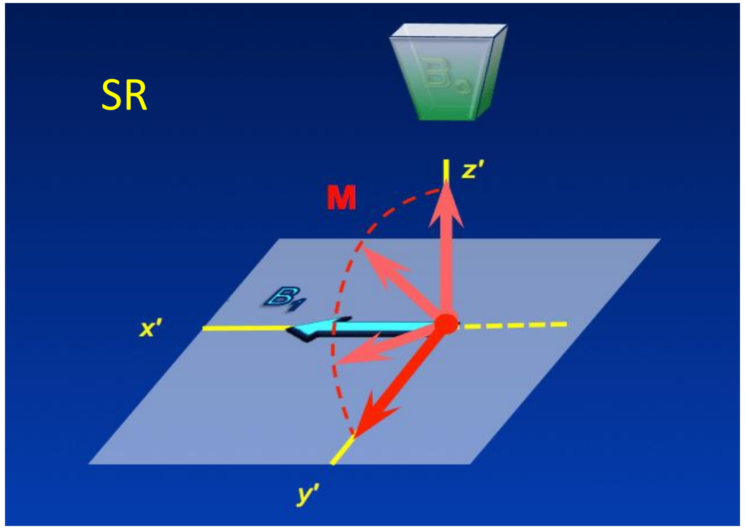
$$\frac{d\vec{M}}{dt} = \gamma\vec{M} \times \overrightarrow{B_{eff}}$$

$$\overrightarrow{B_{eff}} = \left(B_0 + \frac{\Omega}{\gamma}\right)\hat{z}' + B_1\hat{x}'$$

Single pulse experiment (Bloch decay)



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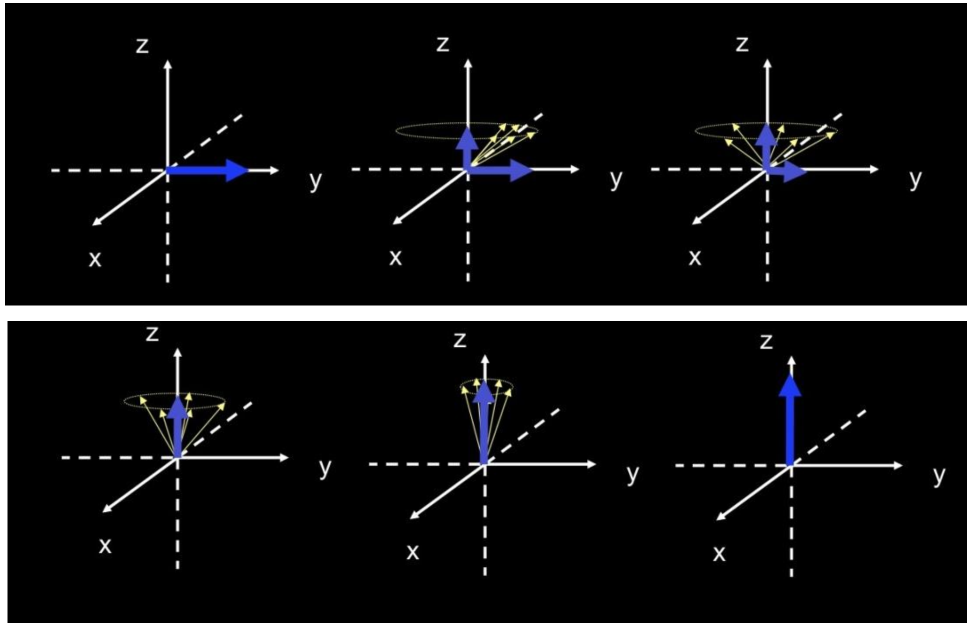
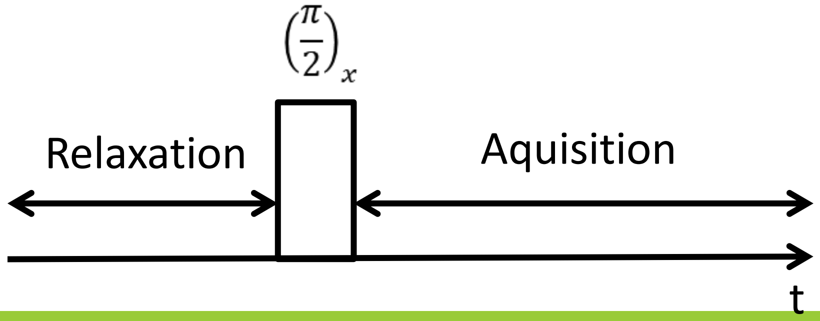
$$\Omega = -\gamma B_0 = \omega_0$$

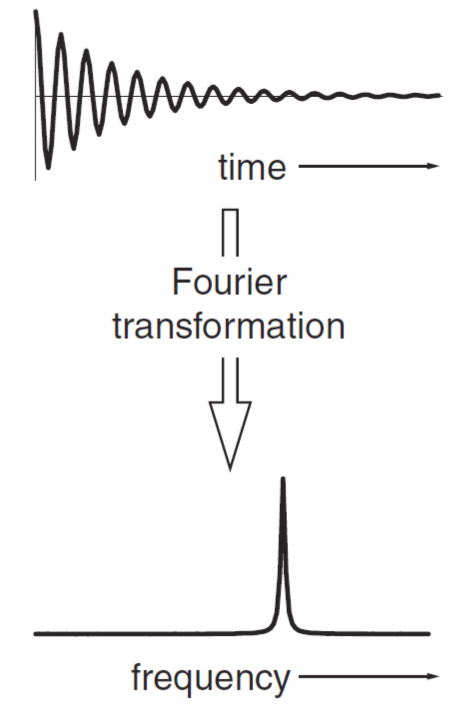
$$\frac{d\vec{M}}{dt} = \gamma B_1 \vec{M} \times \hat{x}'$$

Pulse sequences



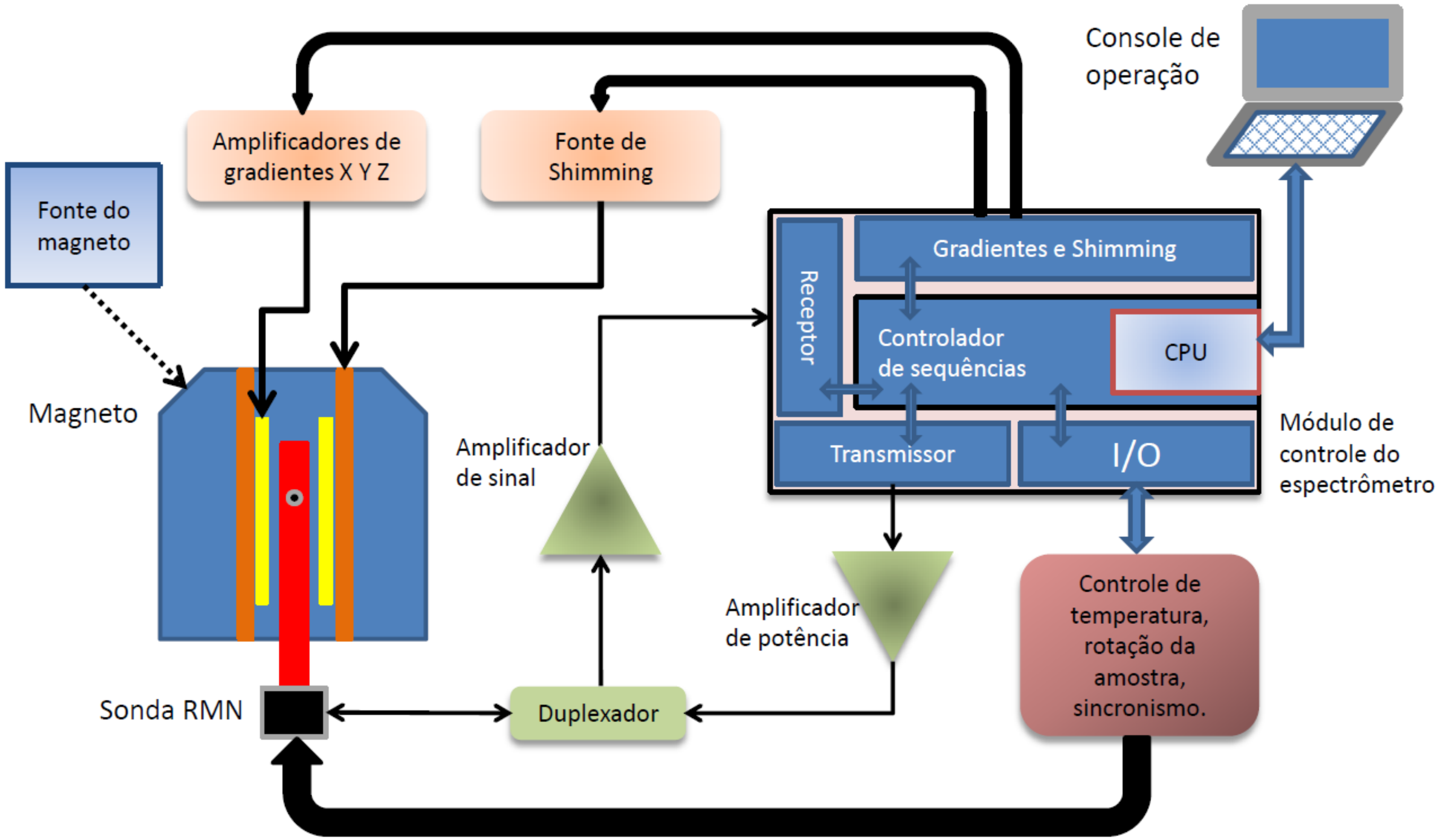


$$V(t) \propto -\frac{d}{dt}M_x(t) = V_0\,\mathrm{sen}(\omega_0 \mathrm{t})\mathrm{e}^{-\frac{\mathrm{t}}{\mathrm{T}_2}}$$

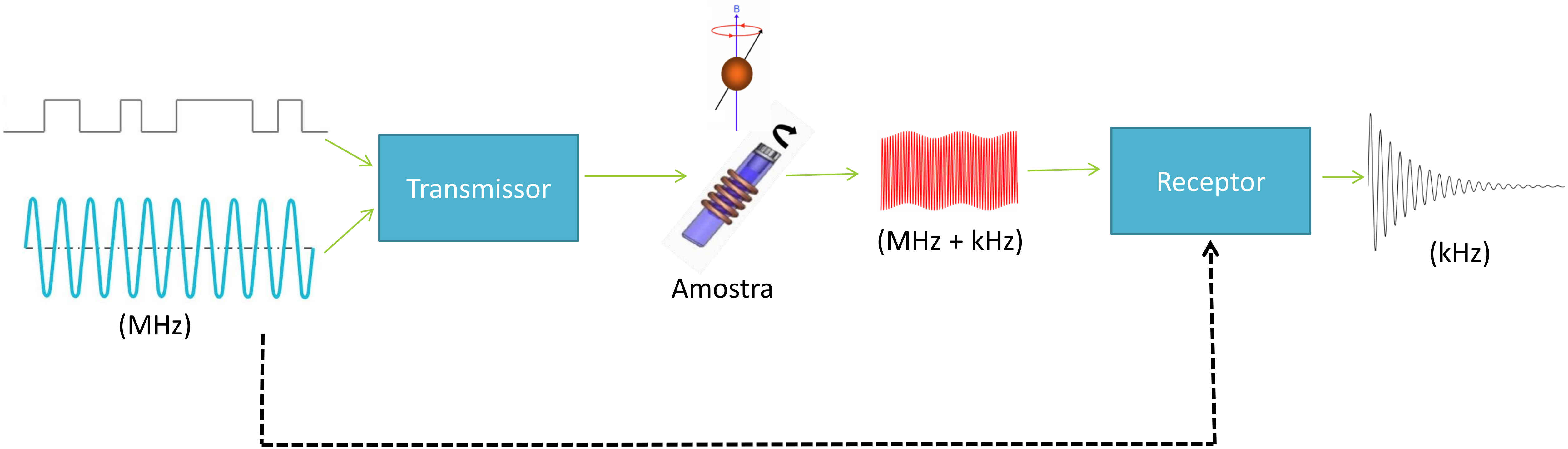


Detalhes experimentais

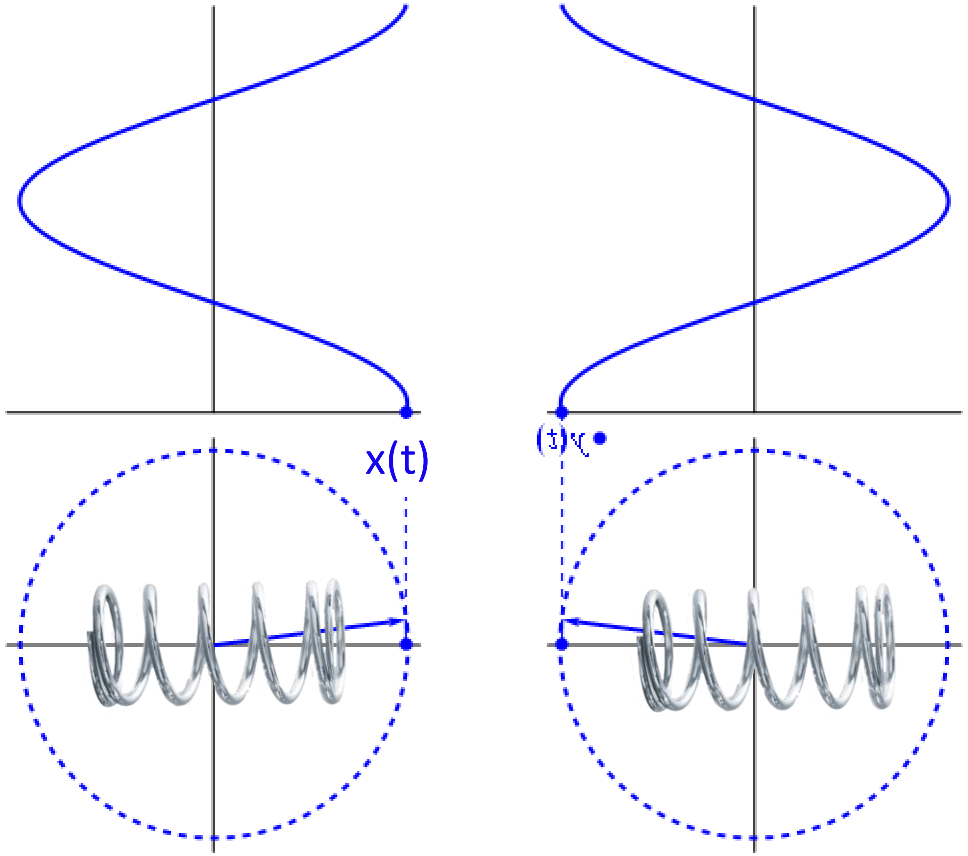
Arquitetura básica de um espectrômetro de RMN



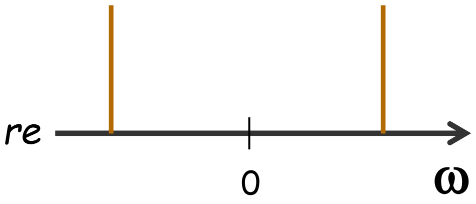
Conceito básico de transmissão e recepção do sinal



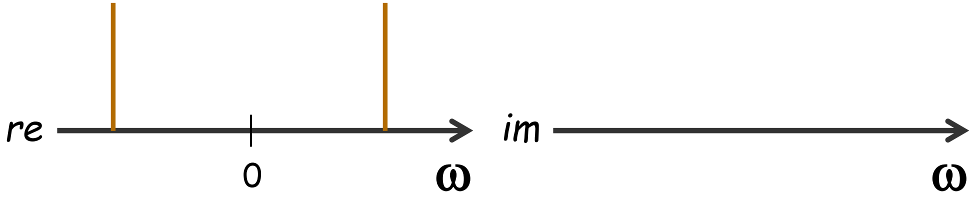
Recepção



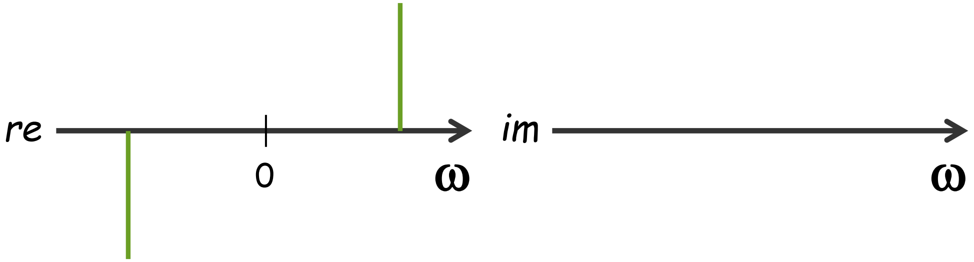
$S_P(t) = \cos\omega t \Rightarrow$



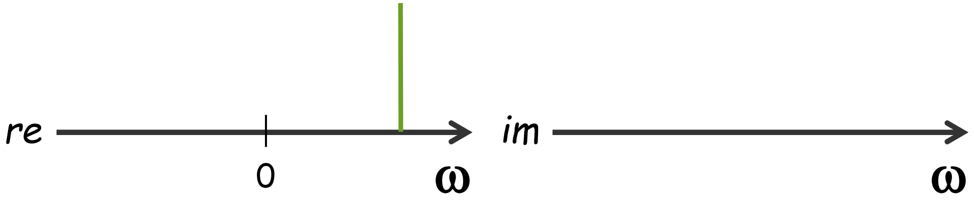
$S_P(t) = \cos\omega t \quad \Rightarrow$



$S_Q(t) = i\sin\omega t \quad \Rightarrow$

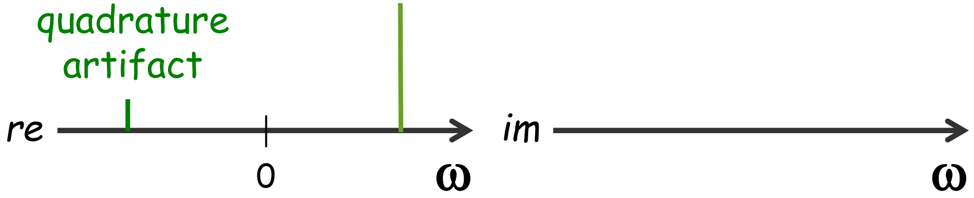


$S\,(t) = \cos\omega t + i\sin\omega t \quad \Rightarrow$

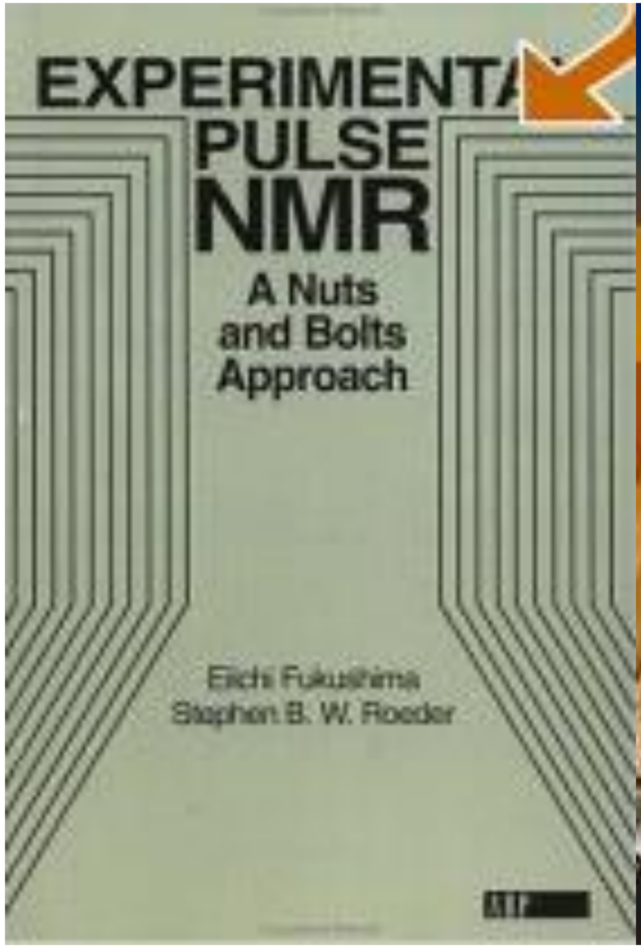


$S\,(t) = A\cos\omega t + iB\sin\omega t \quad \Rightarrow$

$S\,(t) = A\cos\omega t + iA\sin(\omega t+\delta) \quad \Rightarrow$



Bibliografia útil



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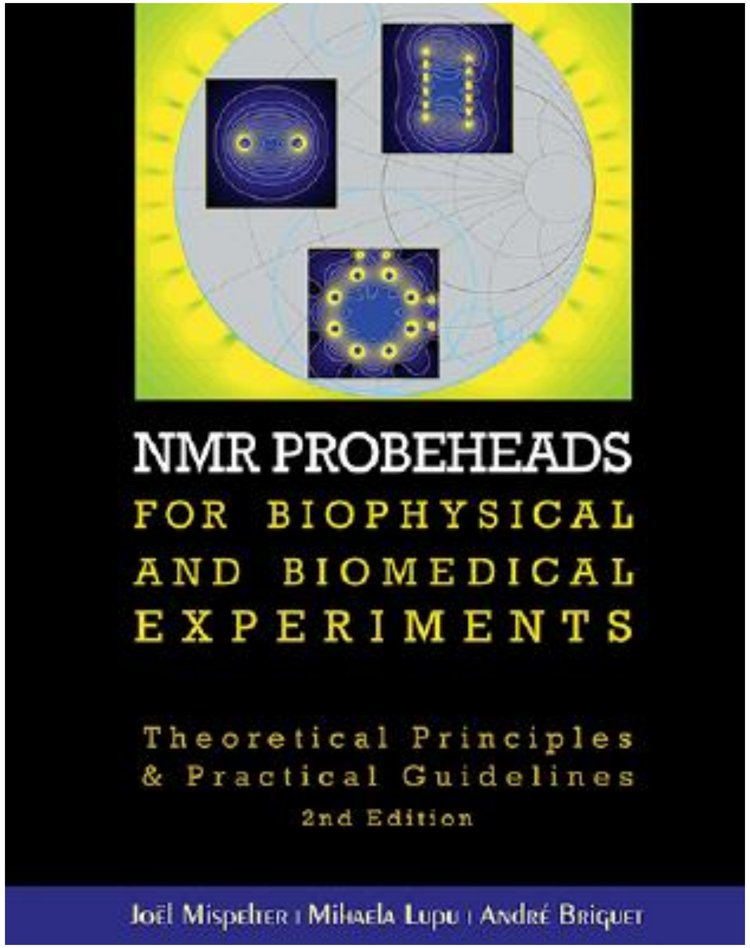

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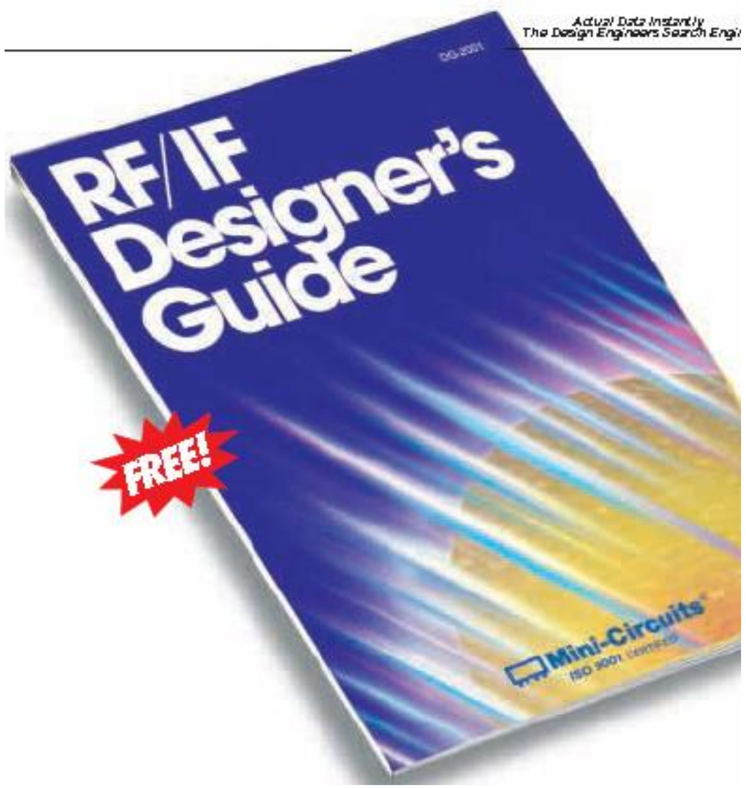

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