

11/2/15 For next week: Keeler Ch 4 Q 1,3,5,7-13
 Stopped at Sensitivity

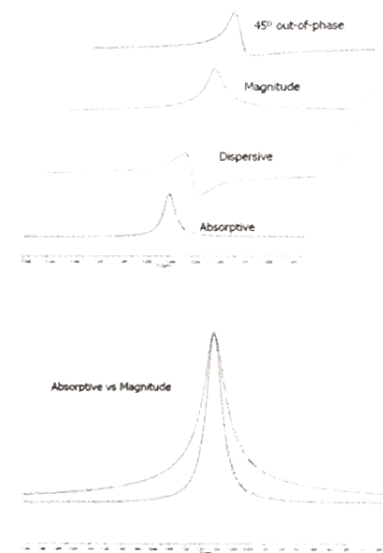
Signal processing

Chris Waudby

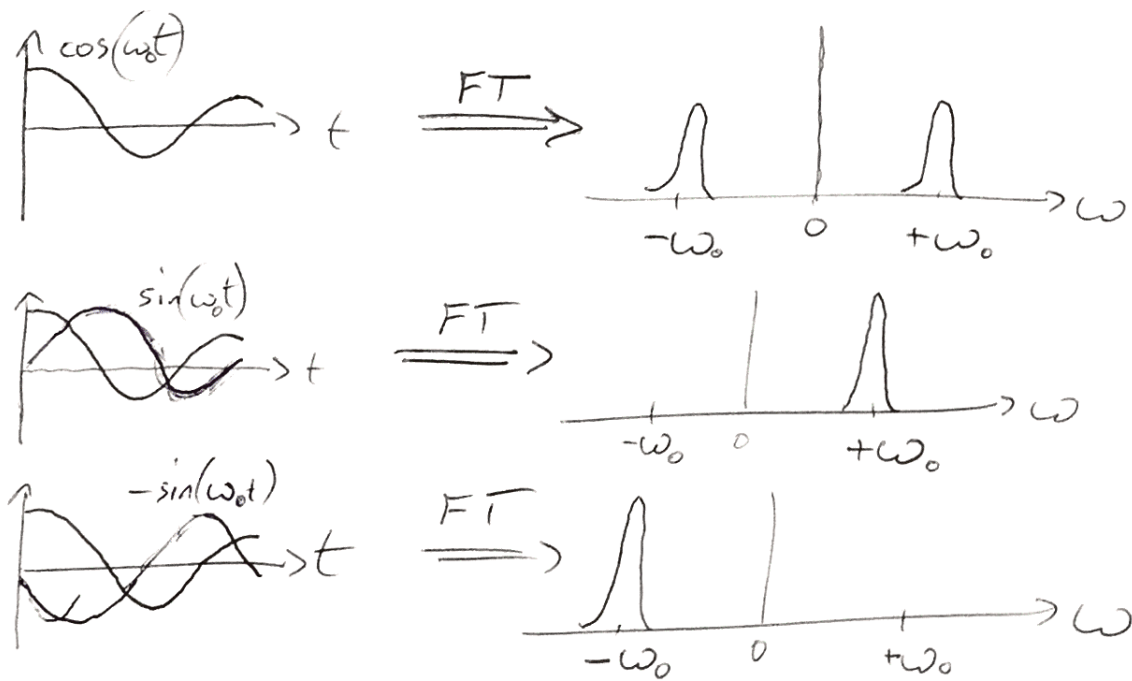
c.waudby@ucl.ac.uk

Quadrature detection and phasing

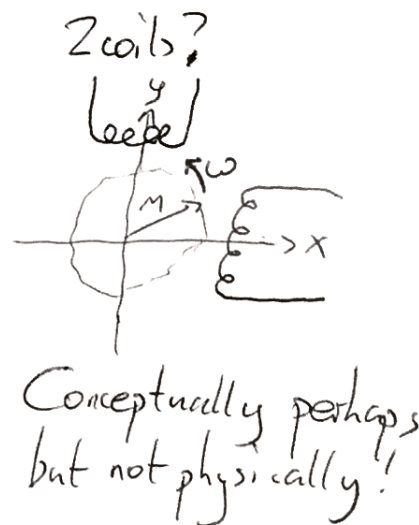
- NMR data are acquired in *quadrature* – they are complex numbers
- Fourier transformation of complex number input gives a complex number output. However, NMR spectra almost always show only the real part of the spectrum – the imaginary part is discarded
- Before doing this it is necessary to *phase* the spectrum to generate absorption mode lineshapes



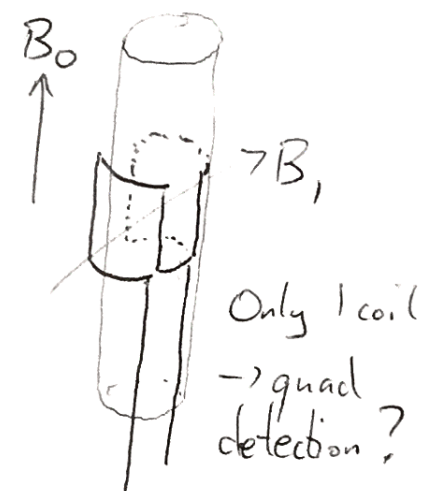
Fourier transformation and quadrature detection



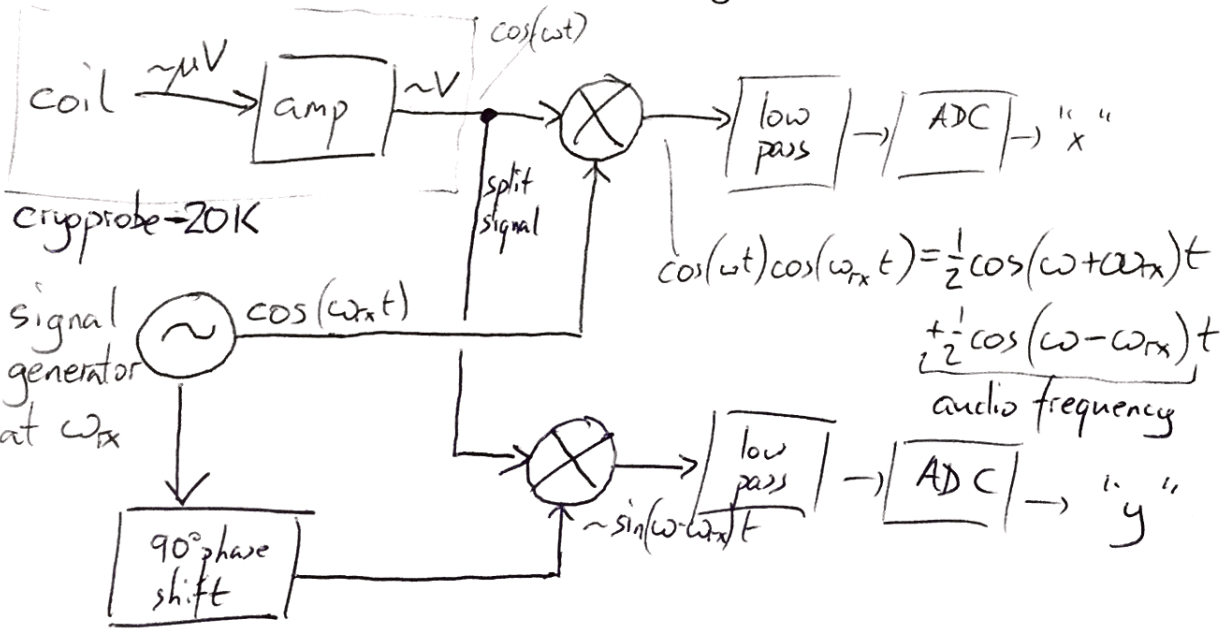
Coil design



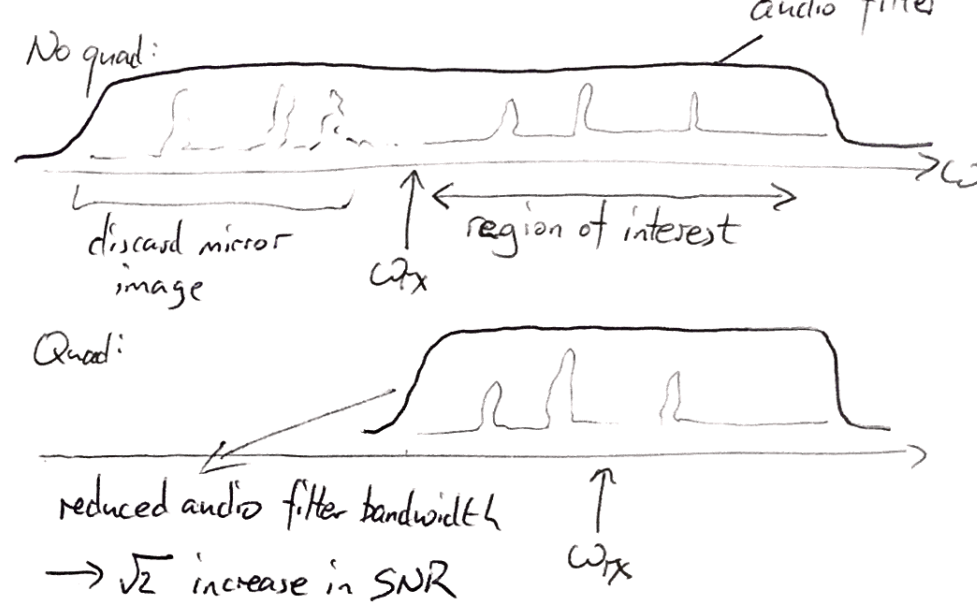
Helmholtz coil:



NB single source - noise in both channels strongly correlated!
Receiver block diagram



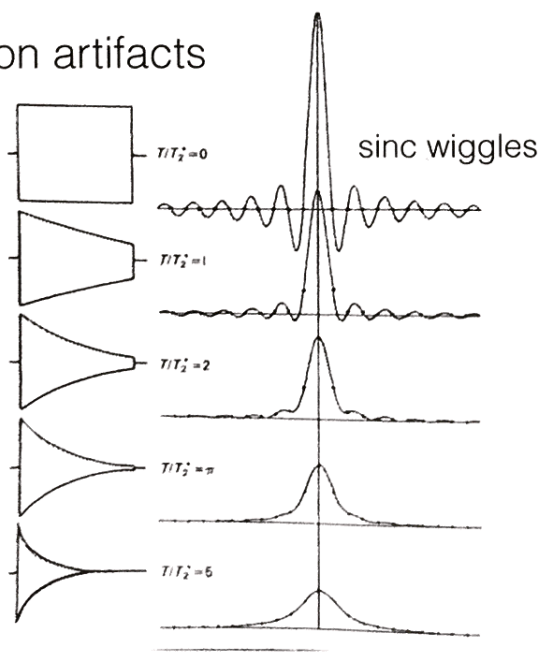
Quadrature detection and sensitivity



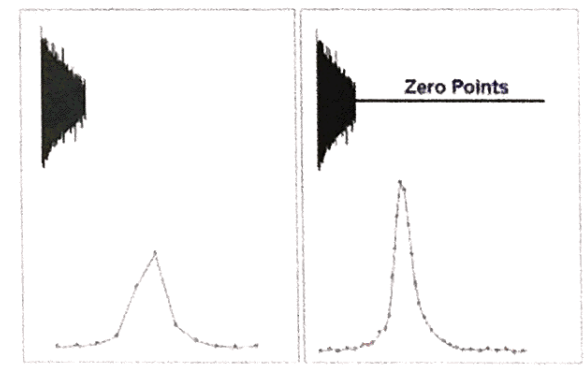
Truncation artifacts

FT of square box = sinc

$\text{sinc } x = \frac{\sin x}{x}$



Zero filling



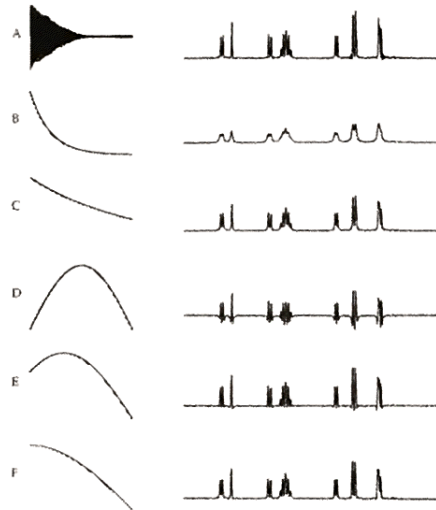
N.B. FFT requires 2^n points

⇒ ZF at least once, more if not originally $\sim 2^n$

number of points in = number of points out

Window functions (apodization)

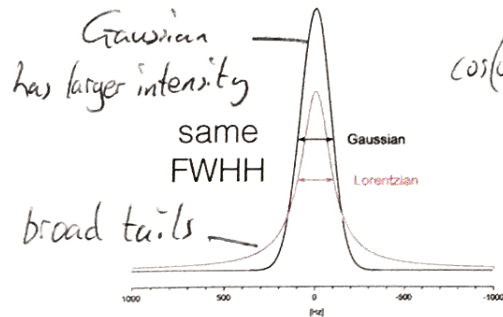
- Multiplication of time-domain signal, $s(t)$, by window function, $h(t)$, prior to Fourier transformation
- Wide selection of window functions for different purposes:
 - suppression of sinc wiggles
 - enhanced sensitivity
 - enhanced resolution
 - better lineshapes



Matched filter:

$S(t) = e^{-R_2 t} \Rightarrow$ choose window function $= e^{-R_2 t}$ for optimal SNR

Lorentz-to-Gauss functions



$$\cos(\omega_0 t) e^{-Rt} \xleftrightarrow{FT} \frac{R^2}{(\omega - \omega_0)^2 + R^2} \text{ Lorentzian}$$

$$\downarrow \times e^{+Rt}$$

$$\cos(\omega_0 t)$$

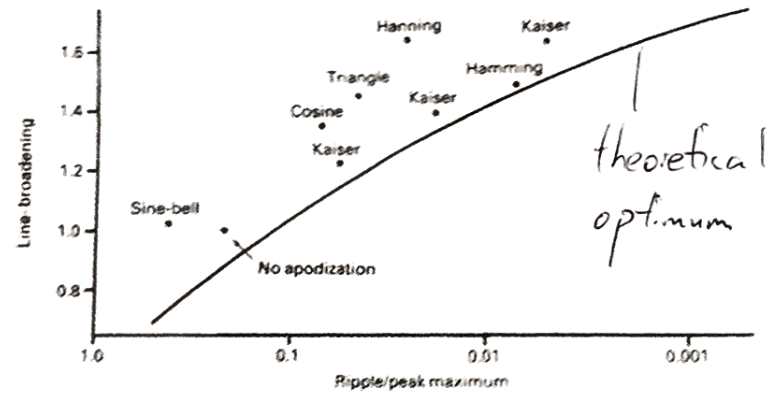
$$\downarrow \times e^{-\sigma^2 t}$$

$$\cos(\omega_0 t) e^{-\sigma^2 t} \xleftrightarrow{FT} \exp\left[-\frac{(\omega - \omega_0)^2}{\sigma^2}\right] \text{ Gaussian}$$

<http://anorganik.uni-tuebingen.de/klaus/nmr/processing/index.php?p=convolution/gm>

More fiddly - need to choose R, σ
- may not be same for all peaks!

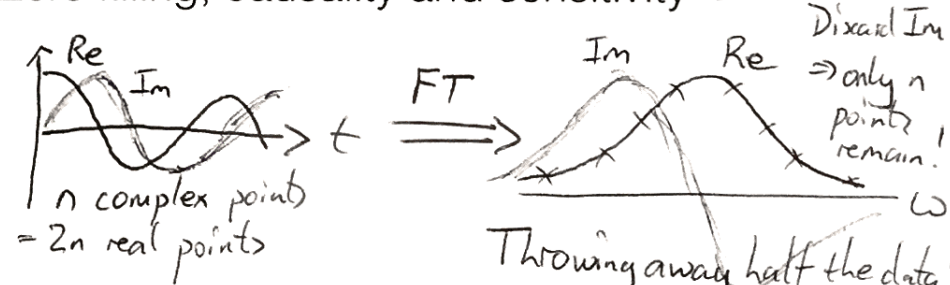
Window functions (apodization)



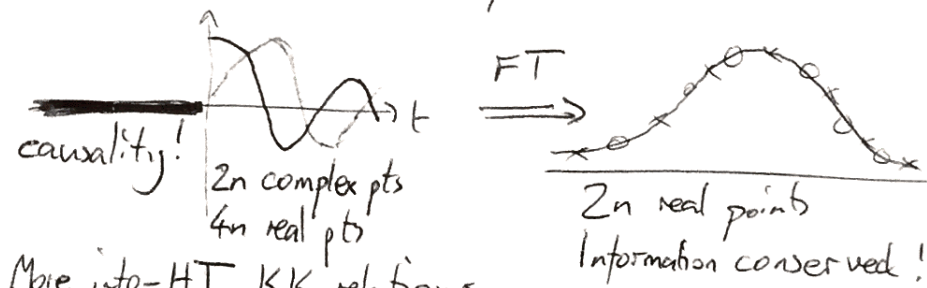
Ernst et al. Principles of NMR in One and Two Dimensions

Subtlety - due to receiver design noise in Re and Im is same in direct dimension - no sensitivity benefit!

Zero filling, causality and sensitivity



But we know more about the signal:



More info - HT, KK relations