

# **Rapid Scan Coils and Resonators**

**by George Rinard**

# Bandwidth of signal

Fourier transform of a Lorentzian line is an exponential.

$$M(f) = \exp\left(-\frac{2\pi f}{a\gamma T_2}\right)$$

Define the bandwidth of the signal as equal to the frequency where the exponential frequency function has decayed to  $\exp(-N)$

$$BW_s = N \frac{\gamma}{2\pi} aT_2$$

# Example – Allowed Q

$$\Delta B_{pp} = 0.10 \text{ G}, T_2 \sim 0.6 \mu\text{s}$$

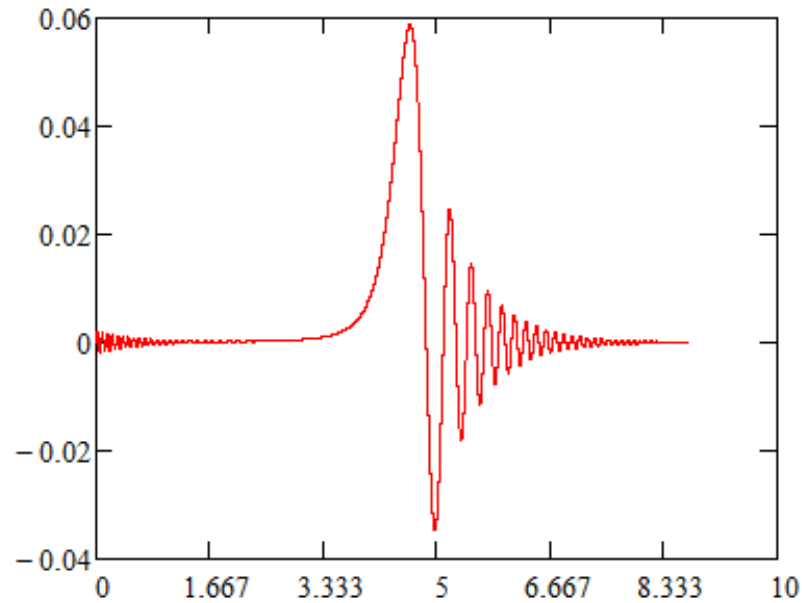
$$N = 5 \text{ Scan Width} = 10 \text{ G}$$

EPR Measurement Scenario	Scan Time	Scan Rate (G/s)	Signal Bandwidth	VHF Q (250 MHz)	L-Band Q (1 GHz)	X-Band Q (9.5 GHz)
Direct - CW	60 s	0.083	1.4Hz	$9 \times 10^7$	$3.6 \times 10^8$	$3.4 \times 10^9$
Fld. Mod. - CW	60 s	0.083	100 kHz	1,250	5,000	47,500
Direct - RS	8.7 $\mu\text{s}$	$1.2 \times 10^6$	9.6 MHz	13	52	492

# RS Absorption Spectrum

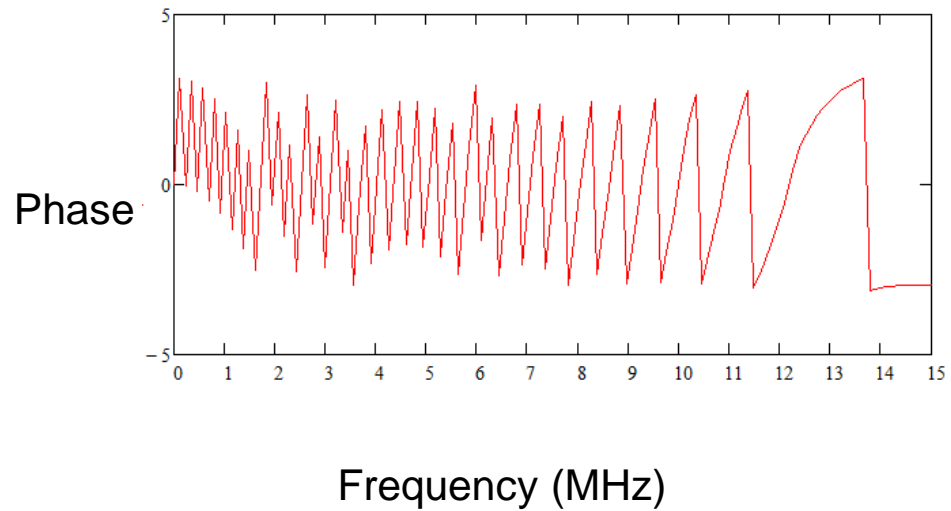
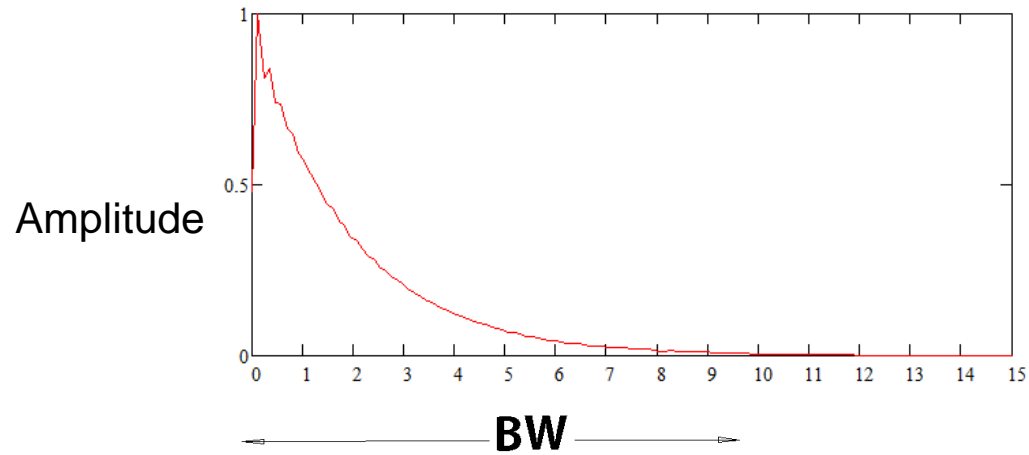
$T_1 = T_2 = 600$  ns    $N = 5$    Scan Width = 10 G   Scan Time =  $8.7\mu\text{s}$

Vepr

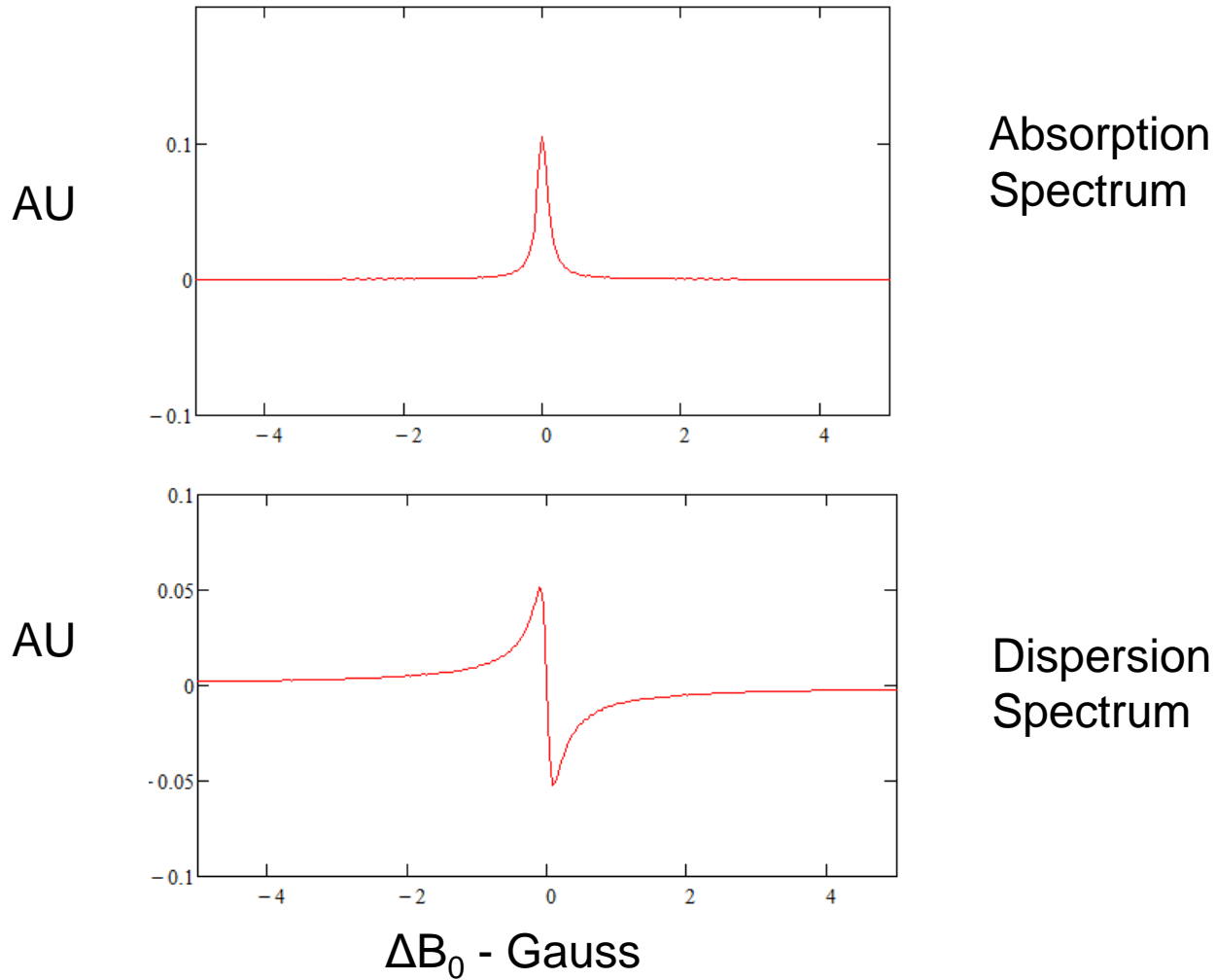


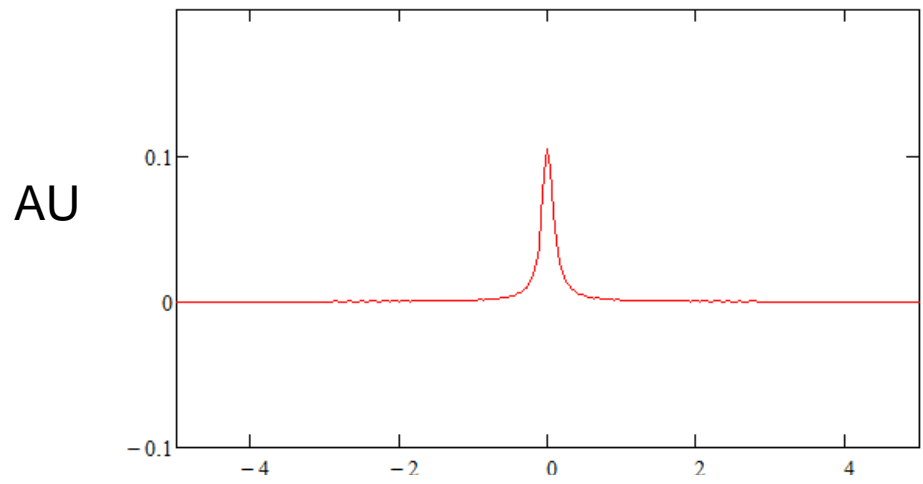
Time ( $\mu\text{s}$ )

# Frequency Spectrum for RS Signal

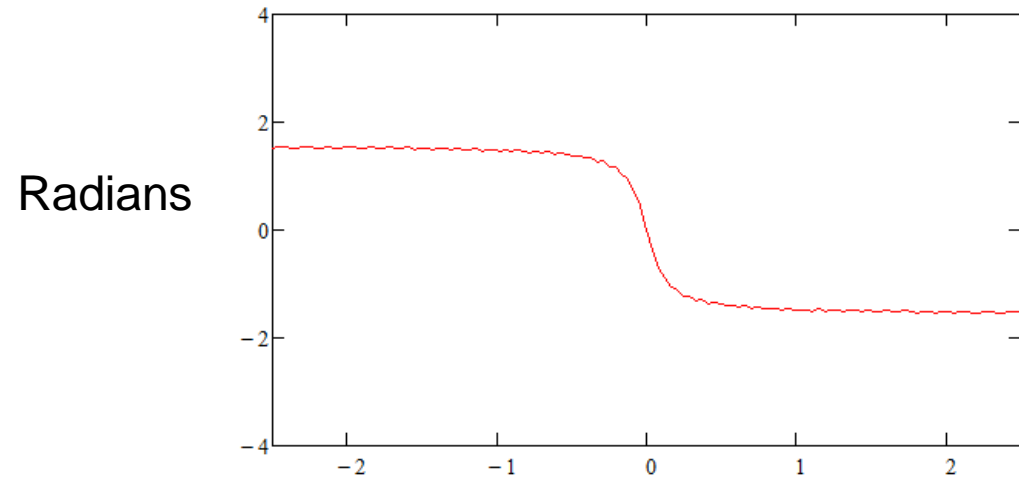


# Deconvolution of Rapid Scan Signal





Absorption Spectrum



Phase

$\Delta B_0$  - Gauss

# Conventional CW Resonators

- Can be penetrated by 100 kHz field modulation
- Modulation coils may not provide sufficiently uniform field over the sample; e.g., 0.1% non-uniformity causes  $\sim 0.1\%$  line broadening.
- Reflected power may limit source power and increase the background
- Source phase noise contributes to signal noise.
- Eddy currents in resonator can cause background and limit magnitude of field scan.
- Very good results were obtained with the Bruker Dielectric Resonator by using scan coils with larger volume of uniformity. In these experiments the sample reduced the Q of the resonator from  $\sim 10,000$  to 150.



# Bruker Dielectric Resonator

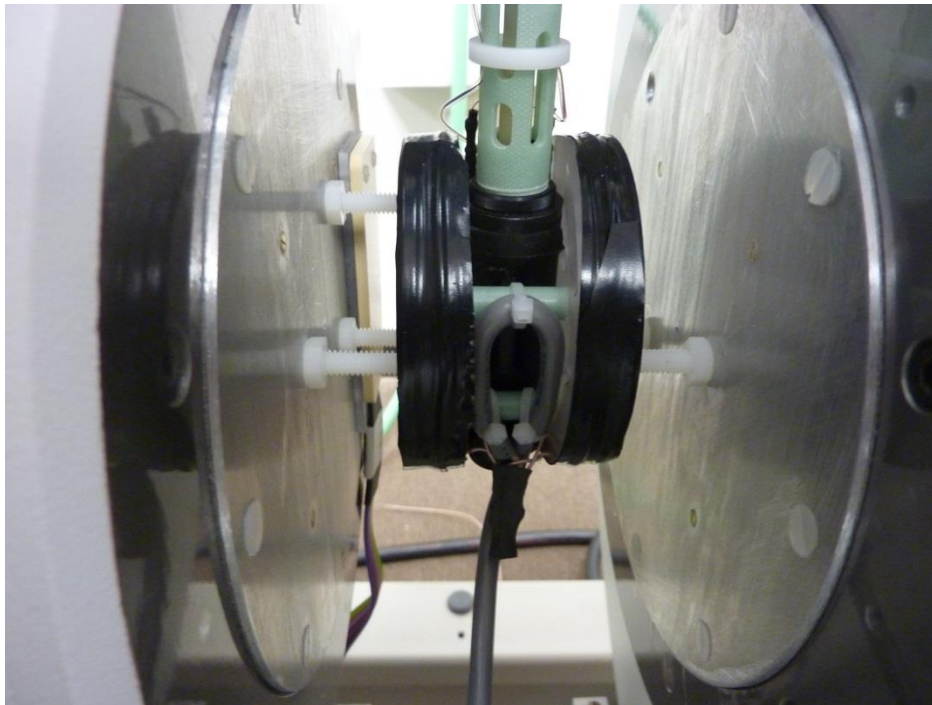
Was used in experiments on Bruker Custom, E500 T, X-Band Spectrometer as described by Debbie Mitchell



# Scan Coils

For coils with Helmholtz spacing the field uniformity is 0.1% over a volume 14 mm diameter.

Rapid scan can be performed with Bruker modulation coils for point samples. For extended samples, larger scan coils are needed.



X-band dielectric resonator with 3" (76 mm) scan coils

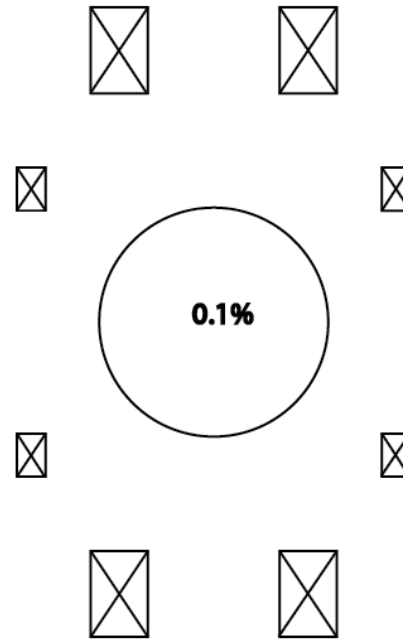
## Scan Coil Size for 0.1% Field Uniformity

Number of Coils	Diameter or Uniform Volume as a Percentage of Coil Diameter	Coil Diameter for 14 mm Diameter Uniform Volume
2 (Helmholtz)	18%	76 mm (3 in.)
4	42%	33 mm (1.3 in.)

# Scan-Coil Uniform Field Volume



Helmholtz Coils

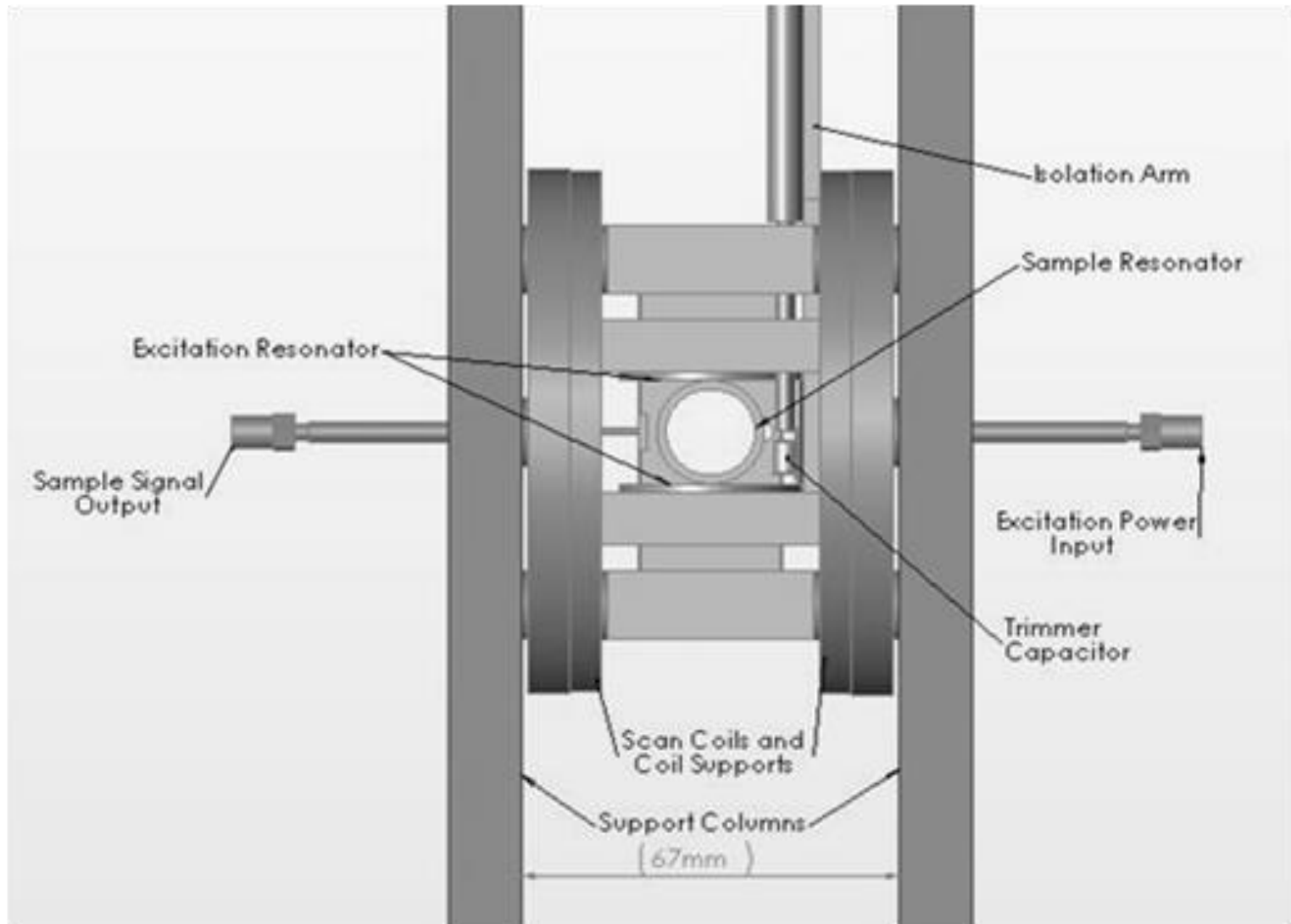


4-Coil System

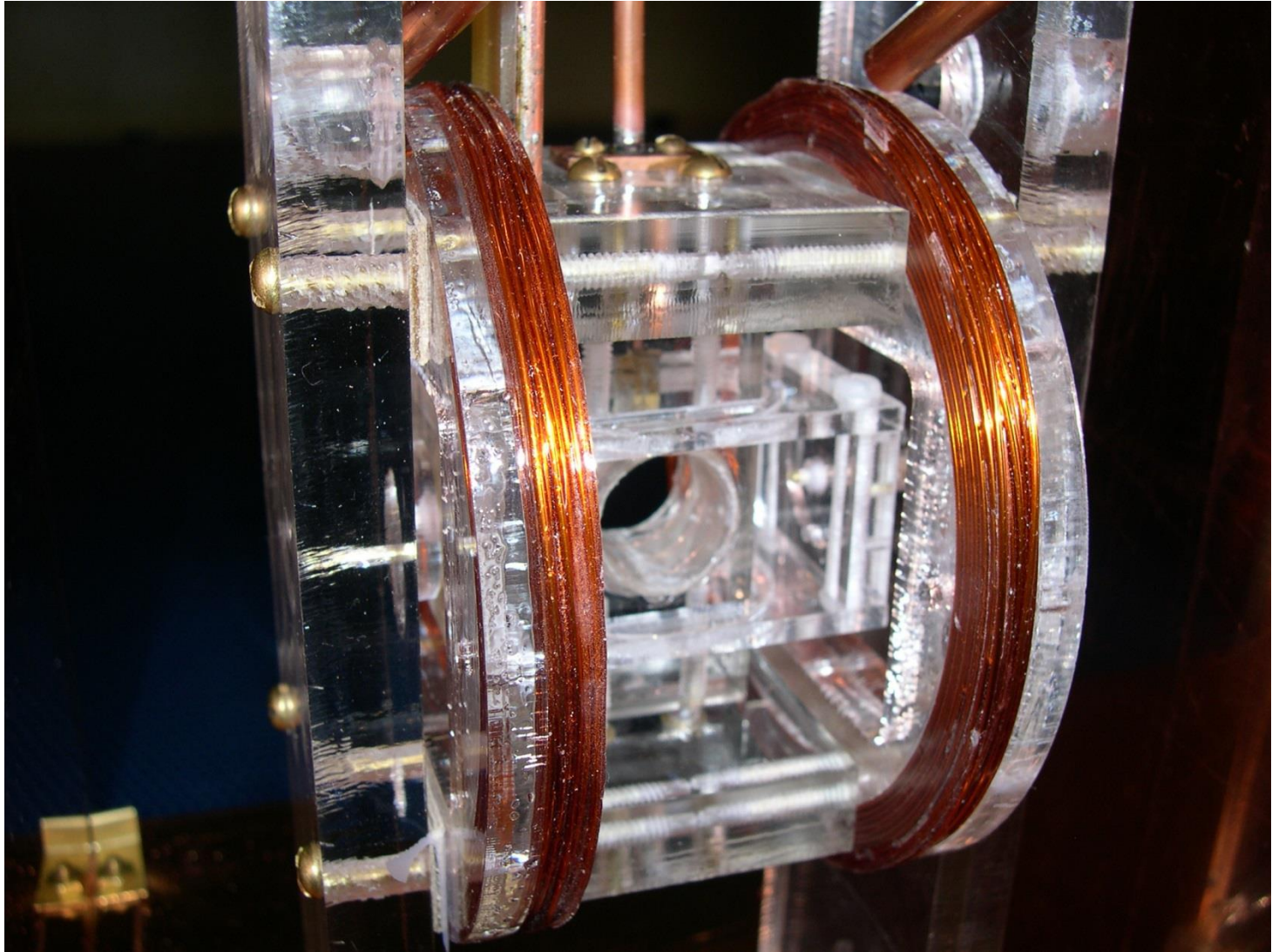
# Resonators Designed for Rapid Scan

- Scan coils that produce more uniform field than typical modulation coils
- Minimize metal to reduce eddy currents
- Crossed-coil design to
  - Isolate source from detector to eliminate source phase noise and allow higher power
  - Reduce background signal
  - Simplify resonator coupling

# Crossed-coil resonator



# 250 MHz cross-coil resonator



# 250 MHz Cross-coil resonator with shield between resonator and scan coils

