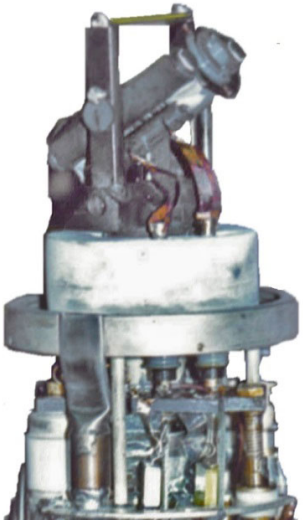
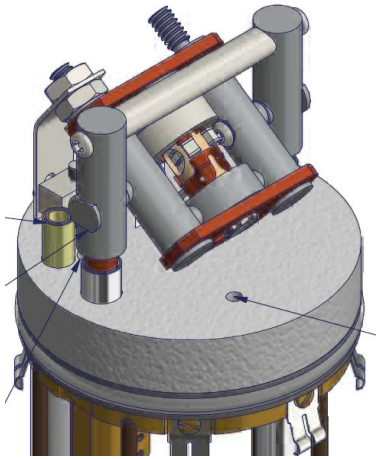
2. HT MAS: MAS up to +500°C

– F. David Doty



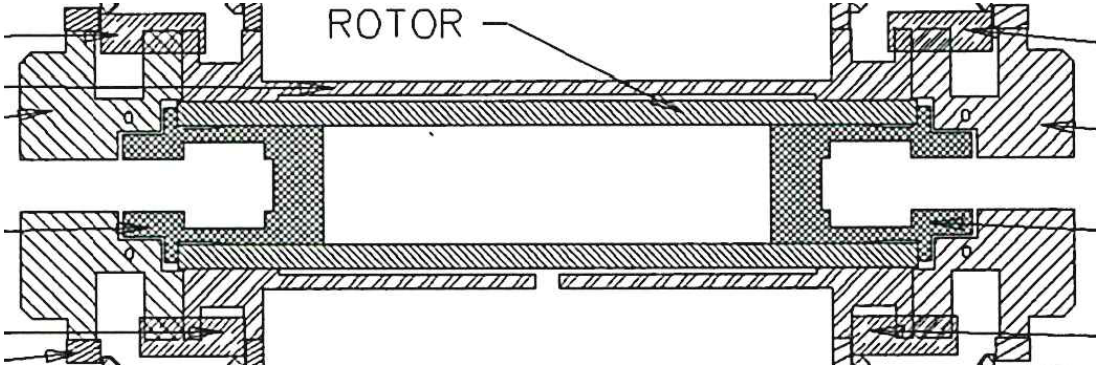
- **Our old 7mm HT MAS had too many issues…**
  limited spinning speed, reliability, tuning…
- **Time for a new probe & HT spinner design**
  one with proven stability over the widest range of temperatures and speeds

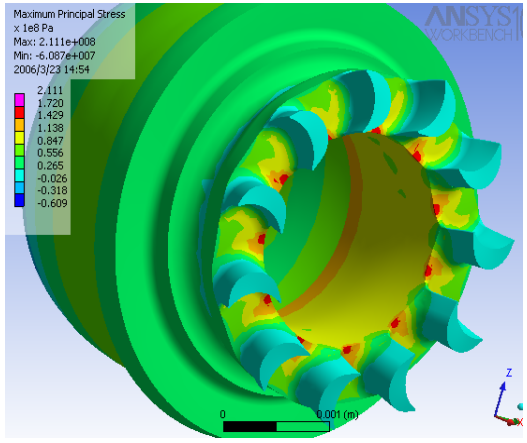


HT MAS with Ultra Low Thermal Gradients

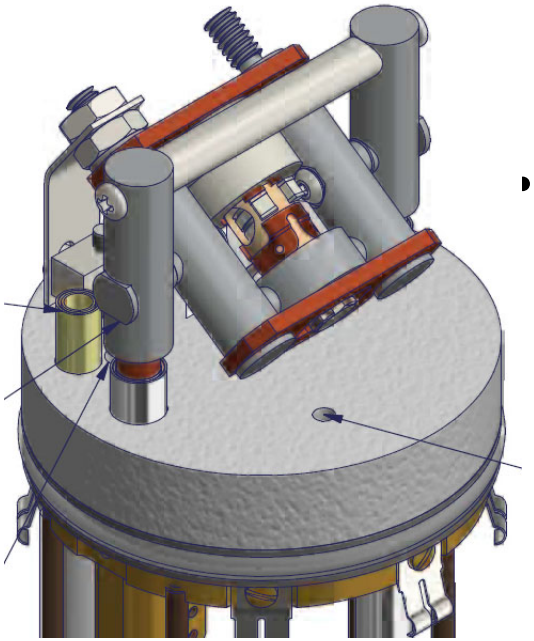
- Radial inflow microturbines for high drive efficiency – for high-speed MAS
- Axially balanced drive – for best stability over wide speed and temperature ranges
- Si_3N_4 stator – robust, low dielectric loss

Spinner assembly	Max speed
4 mm XC4	22 kHz
5 mm XC5	18 kHz
7 mm XC7	12 kHz

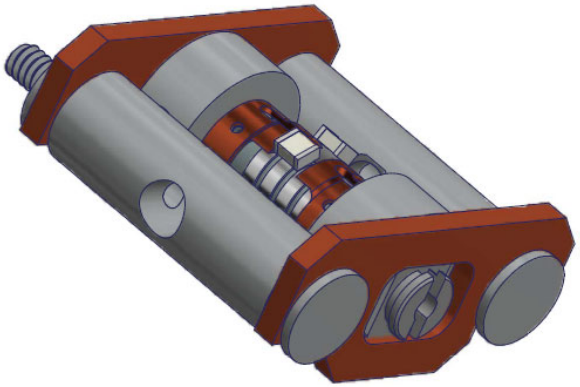


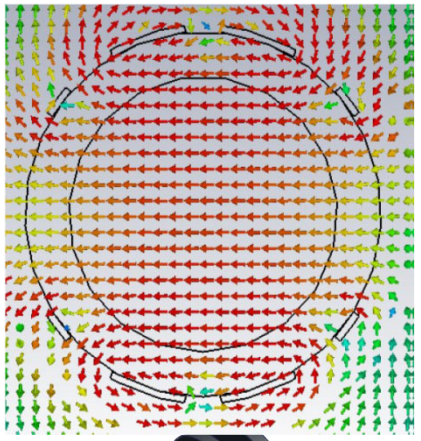


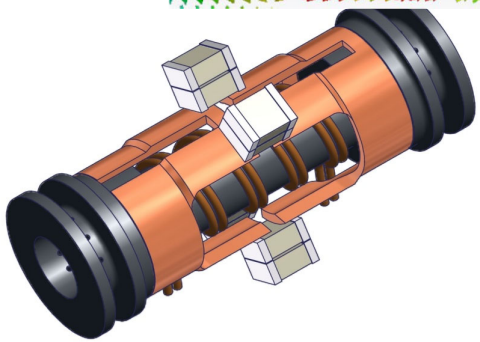
Two-coil RF – Inner solenoid



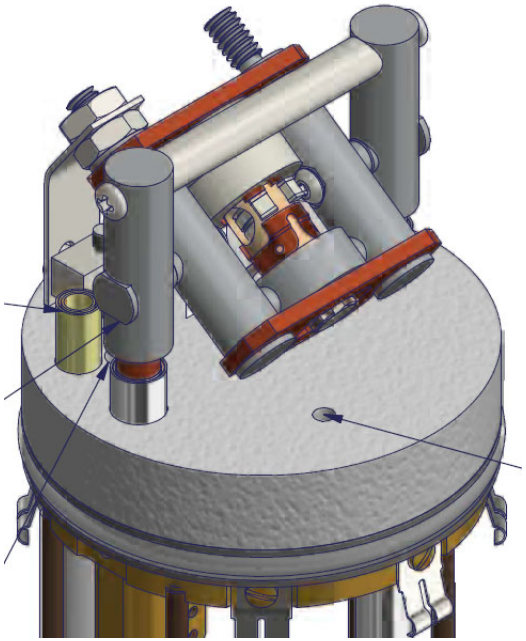
- Outer Low-E coil, 300-750 MHz, high efficiency with long leads, for short pulses & high decoupling
- Inner solenoid for X or X/Y with high efficiency and max S/N



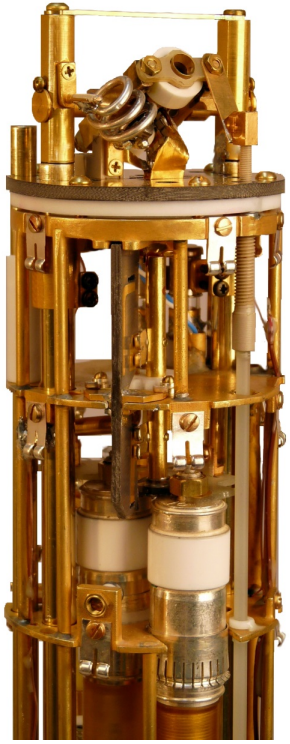




WB Ultra-Range MAS, to +500°C

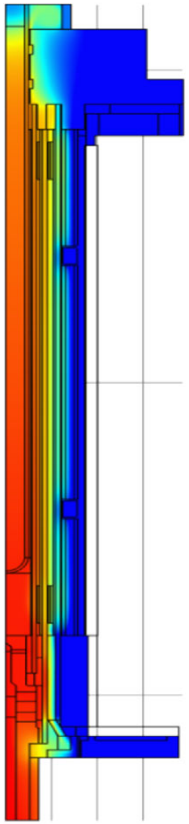


- **Widebore 4-7 mm Ultra-Range**
  Thin-wall metal dewar enclosure
  Hot/cold zone limited to spinner region
- **Broad Temperature Range**
  HT 5mm version: -100 °C to **+500 °C**
- **Broad Tuning Range** ^{31}P to ^{103}Rh
  ^{1}H/X or ^{1}H/X/Y
  Highly optimized rf circuitry
  see **Doty, *Concepts Magn. Reson., 2019***.
- 300 MHz to 750 MHz
- 5 mm: 10 kHz MAS at +500°C
- 7 mm: 7 kHz MAS at +350°C



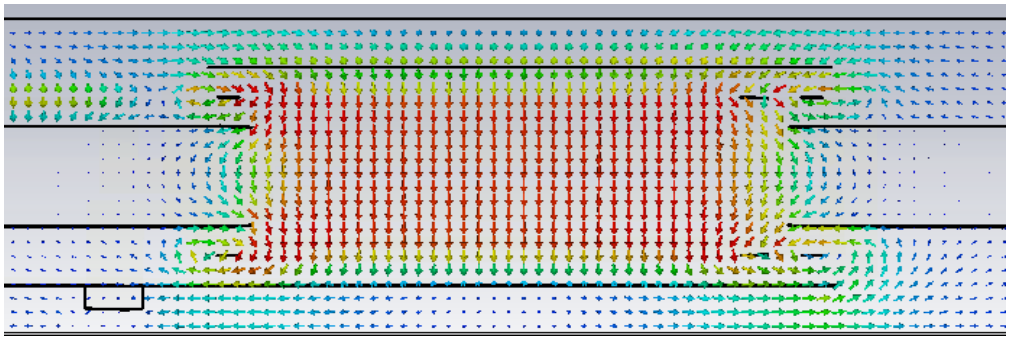
LT Version above
-180°C – 150°C

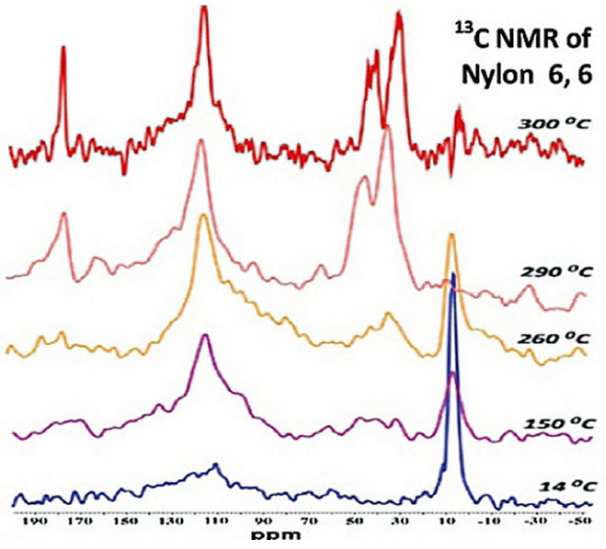
"The Source" - for Custom Liquids Probes



- **Design guided by experience & detailed simulations**
  - **Hundreds of liquids probes delivered, over decades**
  - **Full-wave EM, coils and circuit, using CST**
  - **Thermal & flow, in COMSOL CFD**

Below, B_1 from a novel ^1H coil suitable to >1.2 GHz.

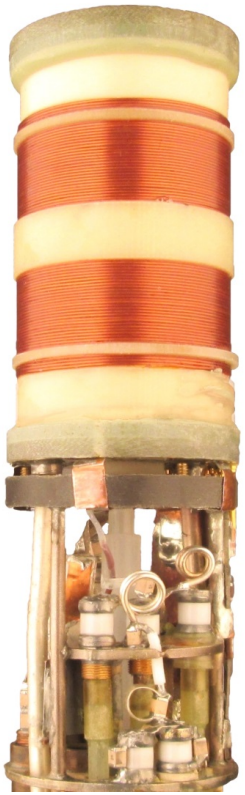




PFG/ Z-Gradient Liquids Probes

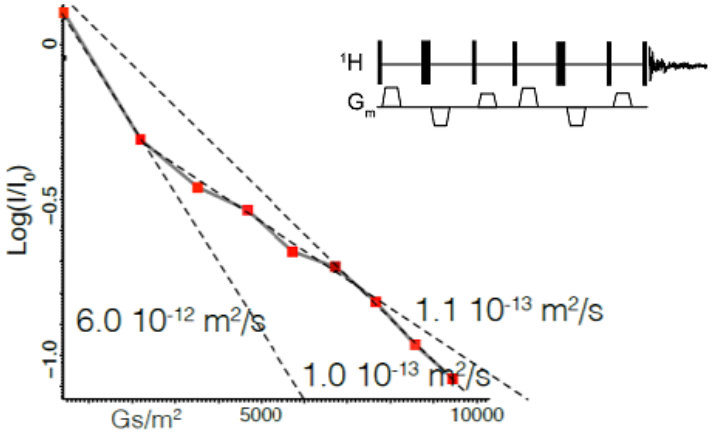
Highest Gradients, 1% uniformity, fastest switching

Gradient Coil Parameter	Model 16-38	Model 20-40C	units
Outside diameter	38	39	mm
Clear I.D.	14	17.5	mm
Continuous gradient	341	180	G/cm
Continuous gradient	3.4	1.8	T/m
Pulse gradient	3320	1380	G/cm
Duty Cycle	1.1%	1.7%	
Gradient gain, α	455	180	mT/A/m
Continuous current	7.5	10	A
Peak current	73	77	A



PFG/ Z-Gradient Liquids Probes

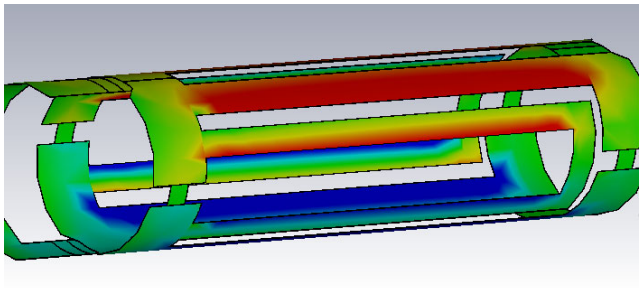
- **Measure the lowest diffusion coefficients - to 10^{-15} m^2/s**
- **Minimal eddy currents**
- **Highest strength gradients**
- **Best thermal stability**
- **Largest sample region with 1% gradient uniformity**
- **^1H/X, direct or indirect**



Stimulated echo measurement of self-diffusion of lipids in hydrated proteoliposomes showing lipids interacting with proteins have reduced mobility.

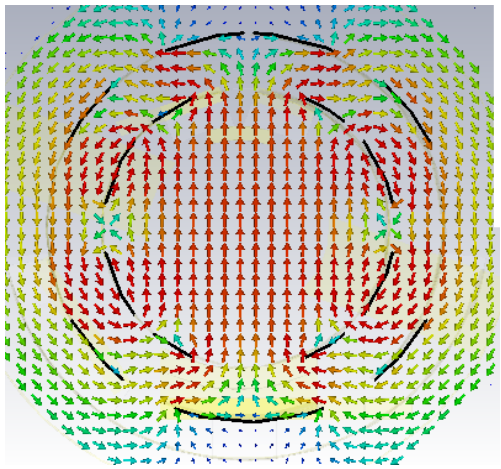
Taking NMR RF to the next level

Novel coils for improved performance in custom high-field liquids probes, optimized by detailed simulations.

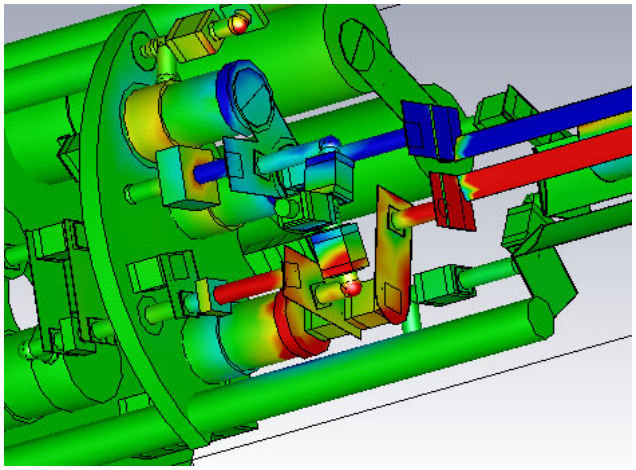


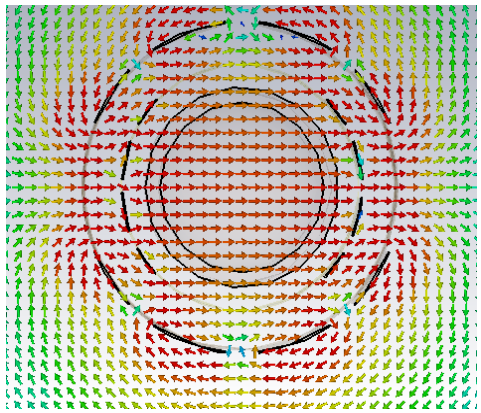
Below, B_1 from a novel high-field outer multi-X coil.

Below, B_1 from a novel inner high-field ^1H coil, suitable to >1.2 GHz.



Below, normal component of the E field on the surface of HF tuning components.





DOTY SCIENTIFIC

HT Liquids/PFG up to +300°C

XVT to 300+°C

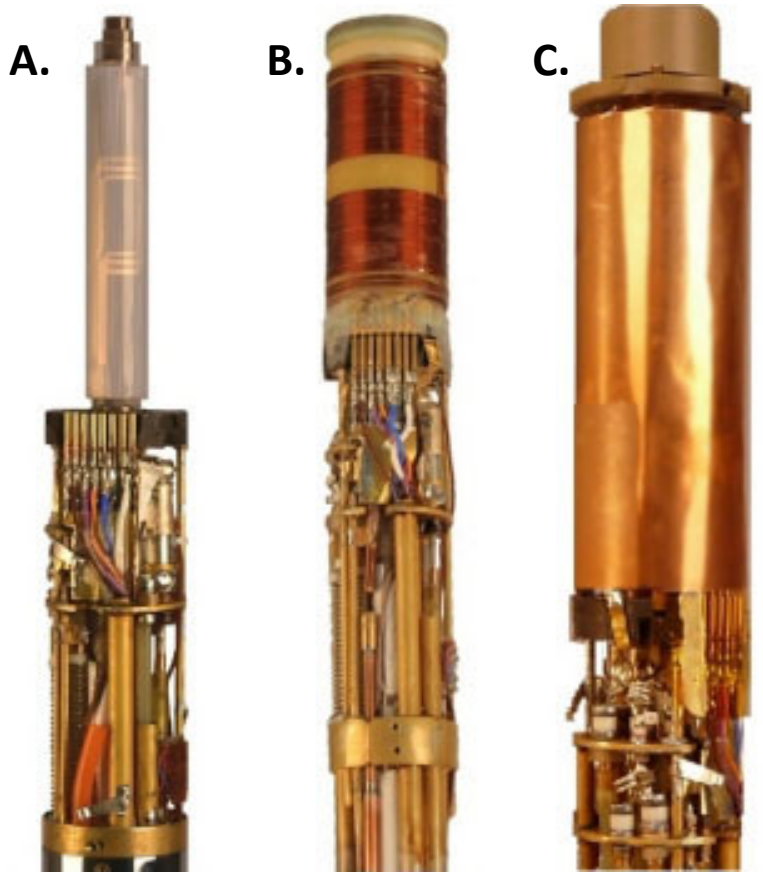
Three views of the HT NB 500 MHz H/X/lock probe with actively shielded Z gradient coils are seen here.

Many versions/options are available:

3 - 20 mm samples in NB magnets

H/F/X/lock, H-F/C/N/lock

In WB: H-F/X/Y/lock



3-Axes Gradient Coils

Most of the gradient coils we supply are Z gradients, for diffusion. We've also made many different 3 axis X-Y-Z gradient coils for MRI microscopy.

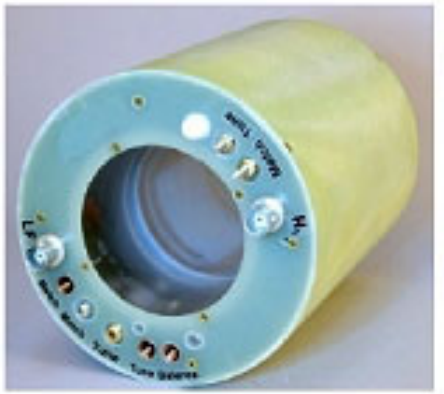
With the SAS-PFG probe that we are developing, there is new need for multi-axis gradients, where it will be useful to be able to generate gradients along the spinning axis at the magic angle and at other angles.

Paul will tell you more about the SAS-PFG probe later.

The World's Best Dual-frequency MR Modules

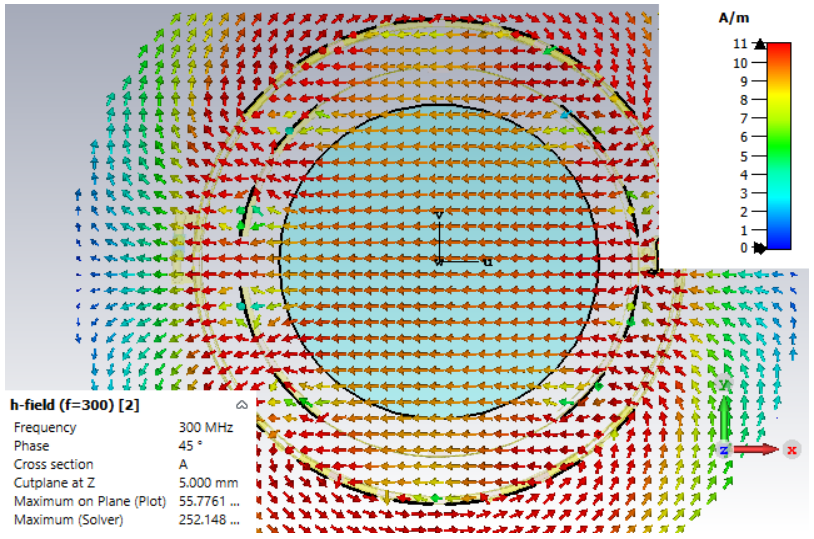
Just got better!

- **Experience from delivering hundreds, over decades**
  - ***Now improved*** **from optimization using detailed full-wave EM simulations**
  - **Simple, stable, clean tuning on both HF and LF**



$^{1}H/X$ MRI RF Volume Coils

- **Patented Litz Coil technology still delivers the best H/X performance for most pre-clinical applications**
  - **S/N, homogeneity, SAR, stability, isolation, robustness**
  - **Multi-X: ^{31}P, ^{23}Na, ^{13}C, ^{2}H, ^{17}O**
  - **Any field: 0.3 – 21 T**
  - **Any size: mouse to primate**

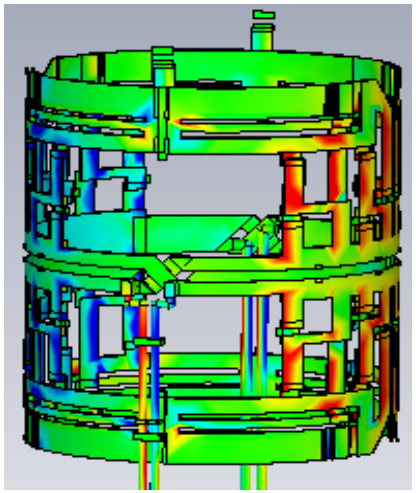


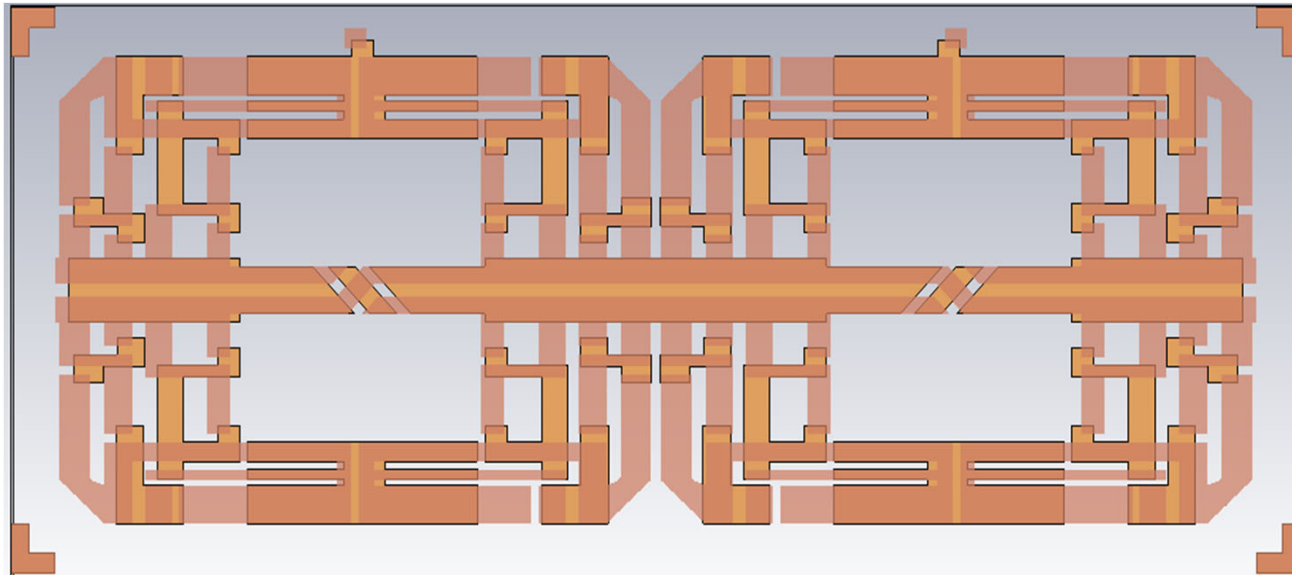
Above, H vector from outer ^{1}H coil in 45 mm 300 MHz $^{1}H/^{129}Xe$

Doty Litz-foil RF Volume Coils

- **What are Doty Litz-foil coils?**
  - **Multi-layer foil patterns utilizing insulated cross-overs to optimally control current paths for best homogeneity, efficiency, and transparency to the orthogonal coil.**

“Simply” the best.





$^{1}H/^{X}$ MRI RF Volume Coils

Insist on RF efficiency and homogeneity specs, and compare.

Example: $^{1}H/^{129}Xe$, 300-MHz, 45mm x 45mm

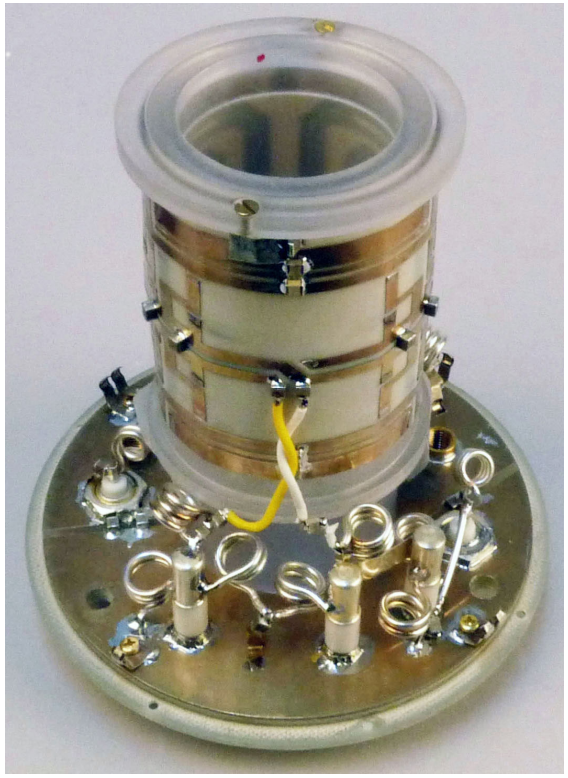
^{129}Xe: $\pi/2$ = 52 μs with 400 W hard pulse

^{1}H: $\pi/2$ = 31 μs with 400 W hard pulse

5% ^{1}H B_1 inhomogeneity over 30-mm length

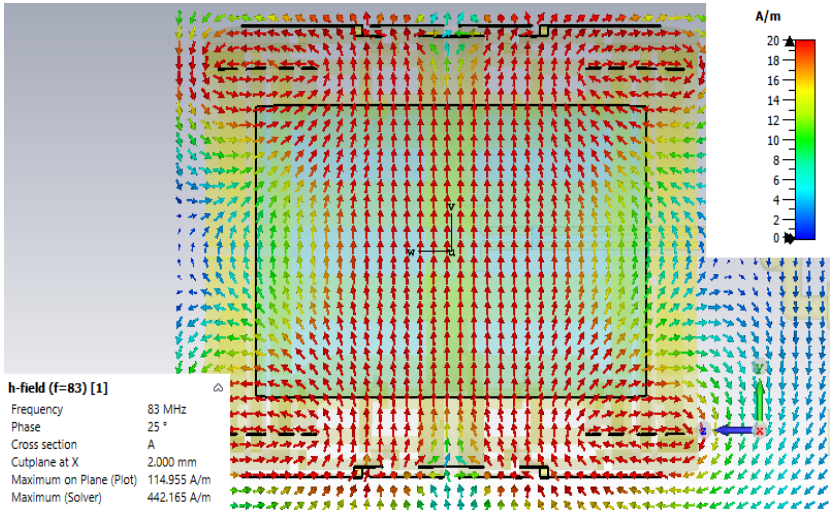
^{1}H SAR at 1W: Peak, 4 W/kg; Ave., 0.15 W/kg.

Maybe there's a reason some others don't publish performance specs?



35-mm H/X [^{31}P, ^{13}C] 400MHz coil

MRI RF Volume Coils



Above, H vector ($2B_1/\mu_0$) from the inner LF coil on the 7T 45-mm $^{1}H/^{129}Xe$ coil described in earlier.

Our paper showing the use of CST in microwave optimizations appeared in ***JMRO***, **Jan. 2021**. Two papers in preparation will provide details on our H/X MR modules and on our latest liquids probes.

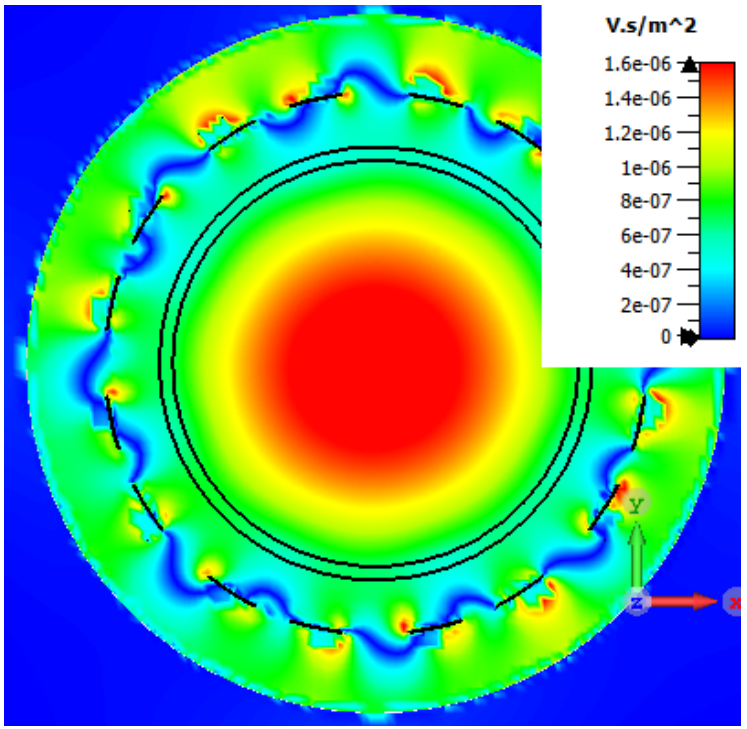
A 35-mm H/X [^{31}P, ^{13}C] 400MHz coil

The Doty Hybrid TEM-Birdcage (HBC)

- Of course, above some frequency and size, circular polarization (CP) becomes better than linear.
- When CP is better, that's what we offer, but we do it better, particularly where space is tight.
- Our unique segmented hybrid TEM-BC beats other CP coils – in S/N, robustness, homogeneity, and tunability over the full range of sample loadings.

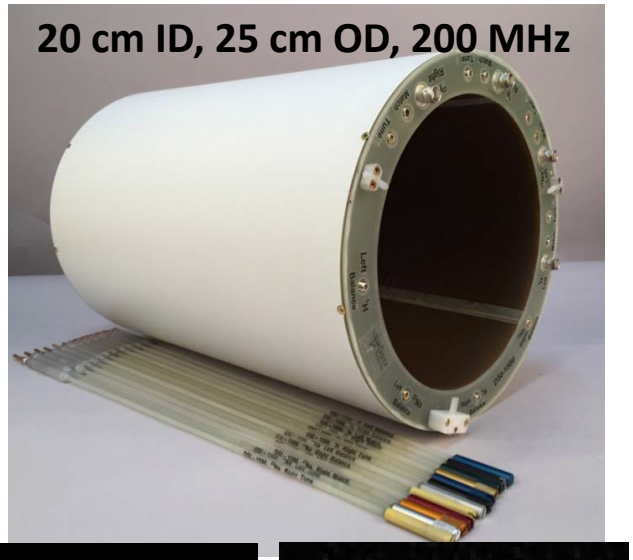
Shown here: B_1 in heavily loaded 400-MHz 11-cm coil that fits inside 15-cm gradient bore.

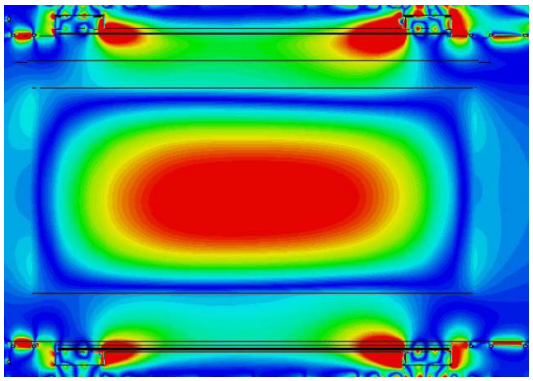
^1H $\pi/2$ = 100 μs with 150-1600 W hard pulse, depending on sample, from mouse to obese rabbit.



The Double-Tuned HBC MR Coil

The unique (Doty) segmented Hybrid BirdCage. A fundamentally better design for high-field large-sample double-tuned (DT) CP volume coils. Unbeatable S/N, homogeneity, stability, and robustness. Available for large samples at all fields.

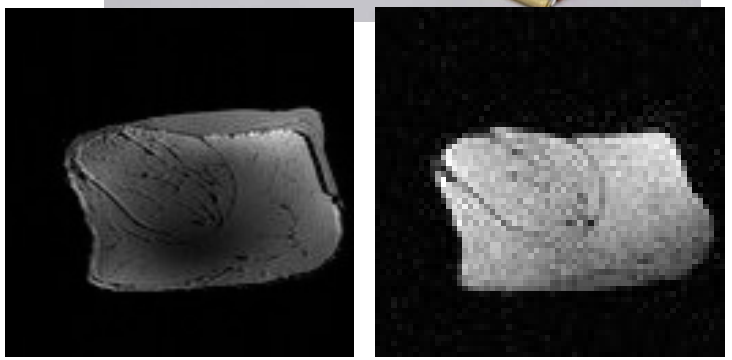




Upper right: 4.7-T $^{1}H/^{23}Na$ DT HBC with 20-cm ID, 25-cm OD.

At left, ^{1}H B_1 in saline sample for this coil.

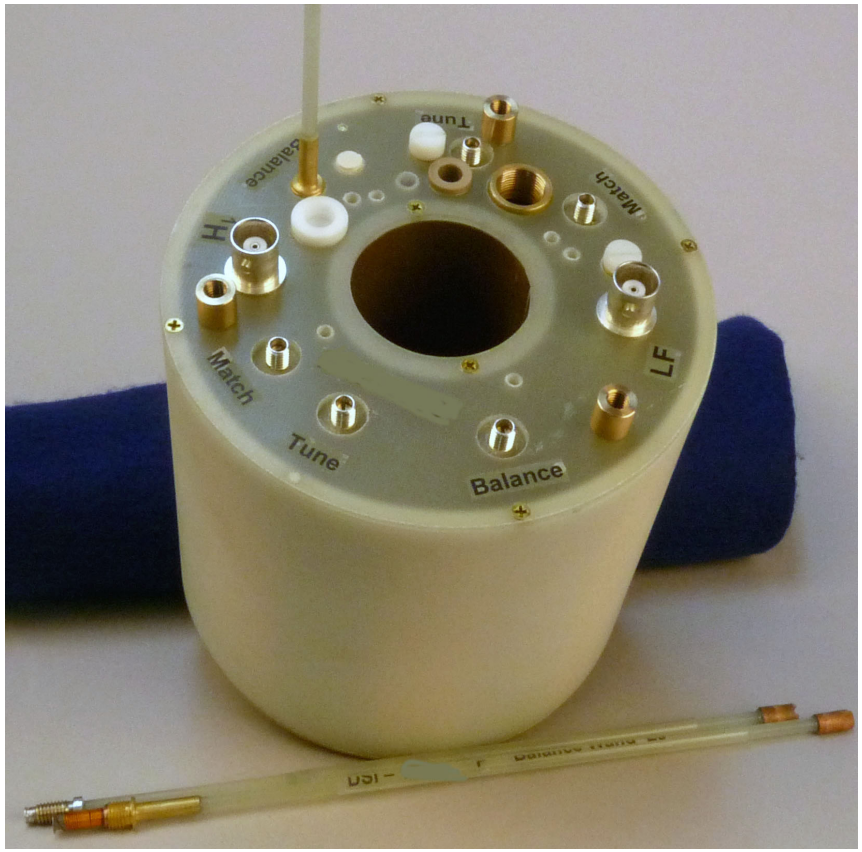
Far Right, ^{23}Na image of a salt-cured ham (9% NaCl) from this coil.



MRI RF Volume Coils

Some recent examples

646 MHz: 35 x 60 mm, ^{1}H HBC
600 MHz: 25 x 22 mm, ^{1}H/^{13}C.
400 MHz: 45 x 45 mm, ^{1}H/^{129}Xe.
400 MHz: 38 x 34 mm, ^{1}H/X, *(X=^{31}P, ^{13}C)*.
400 MHz: 25 x 24 mm, ^{1}H/X, *(X=^{31}P, ^{13}C)*.
300 MHz: 45 x 36 mm, ^{1}H/X, *(X=^{31}P, ^{13}C)*.
300 MHz: 38 x 55 mm, **^{1}H/^{19}F**.
200 MHz: **200 x 160 mm**, ^{1}H/^{23}Na.
128 MHz: 65 x 52 mm, ^{1}H/X, *(X=^{13}C, ^{15}N)*.
13 MHz: 65 x 52 mm, ^{1}H/X, *(X=^{13}C, ^{15}N)*.



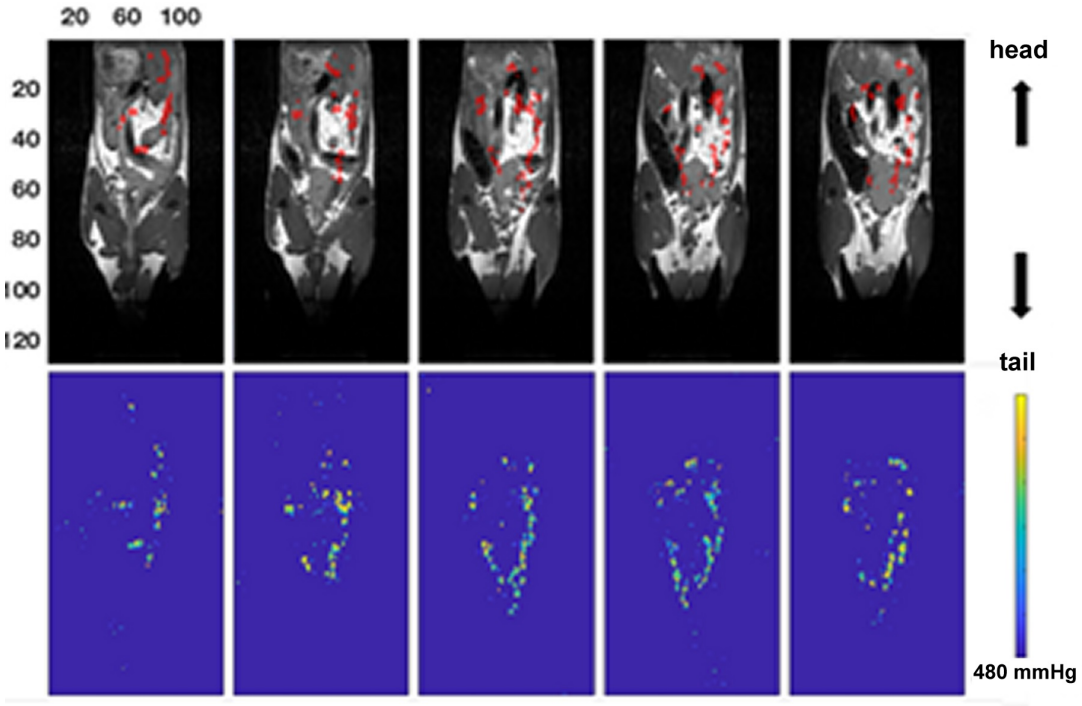
$^{1}H/^{19}F$ MRI RF Volume Coils

- **$^{1}H/^{19}F$ Dual Frequency Coils**
- **Efficient, easy to tune and match over a broad range of sample loadings.**
- **Each channel for TxRx, linearly polarized.**
- **For observe/decouple – with both channels simultaneously.**

DOTY SCIENTIFIC

$^{1}H/^{19}F$ MRI RF Volume Coils

Results from a 300 MHz $^{1}H/^{19}F$ 38 mm Whole Mouse Volume Coil



Top, superimposed ^{19}F (red) and ^{1}H (grayscale image) collected on a mouse for assessing pO_2 via the strong effect of O_2 on the spin-lattice relaxation time of ^{19}F in implanted microcapsules, as O_2 is strongly paramagnetic and shortens T_1 of ^{19}F. Bottom, calculated pO_2 from the ^{19}F MR data. *Vanderbilt Univ.*