Magnetic precision has a name

Update on Metrolab's new developments

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IMMW18 • June 3, 2013 • Brookhaven National Laboratory

Developments since IMMW17

- 3-axis magnetometer family:
  - New probes
- Integrator:
  - Major upgrade to Fast Digital Integrator
- NMR magnetometer:
  - New generation nearing completion (??!)

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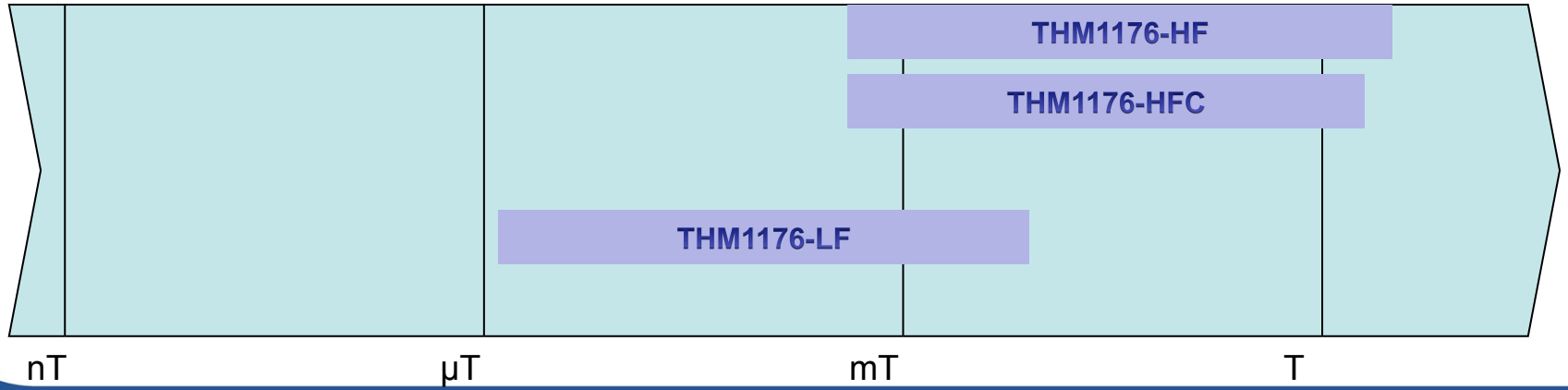
3-axis magnetometers

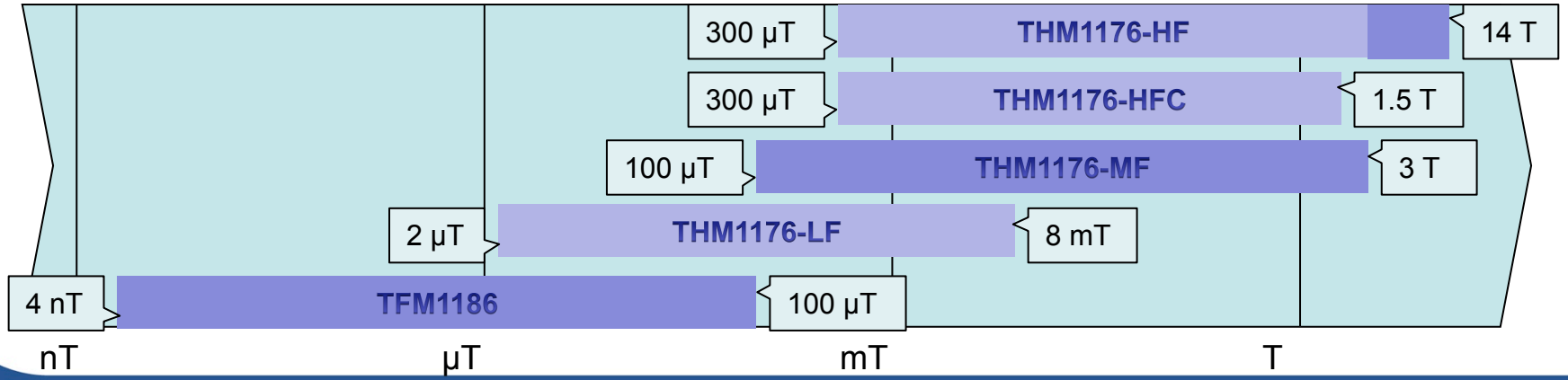
- Compact
- USB Plug & Play
- Optional handheld
- Spectral analysis
- Custom software



3-axis magnetometers (today)

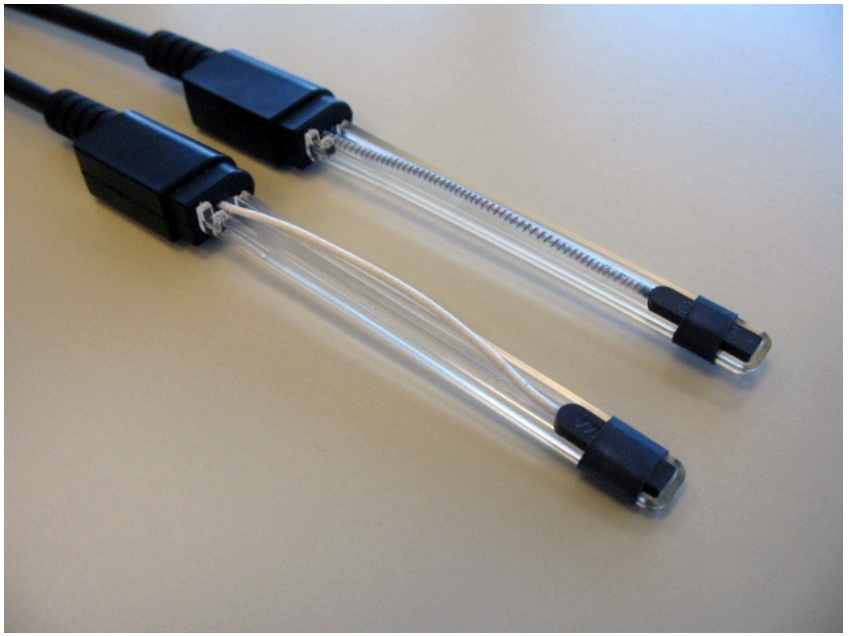
New:

- THM1176-HF:
  extended calibration range
- THM1176-MF:
  new integrated 3-axis Hall
- TFM1186:
  new low-power fluxgate



THM1176-MF

- Sensima MV 403A
- Packaging like Senis (= like Group3: 16.5 x 5.0 x 2.3 mm)
- Ranges: 0.1, 0.3, 1, 3T
- Resolution: 0.1 mT
- Accuracy: ±1%



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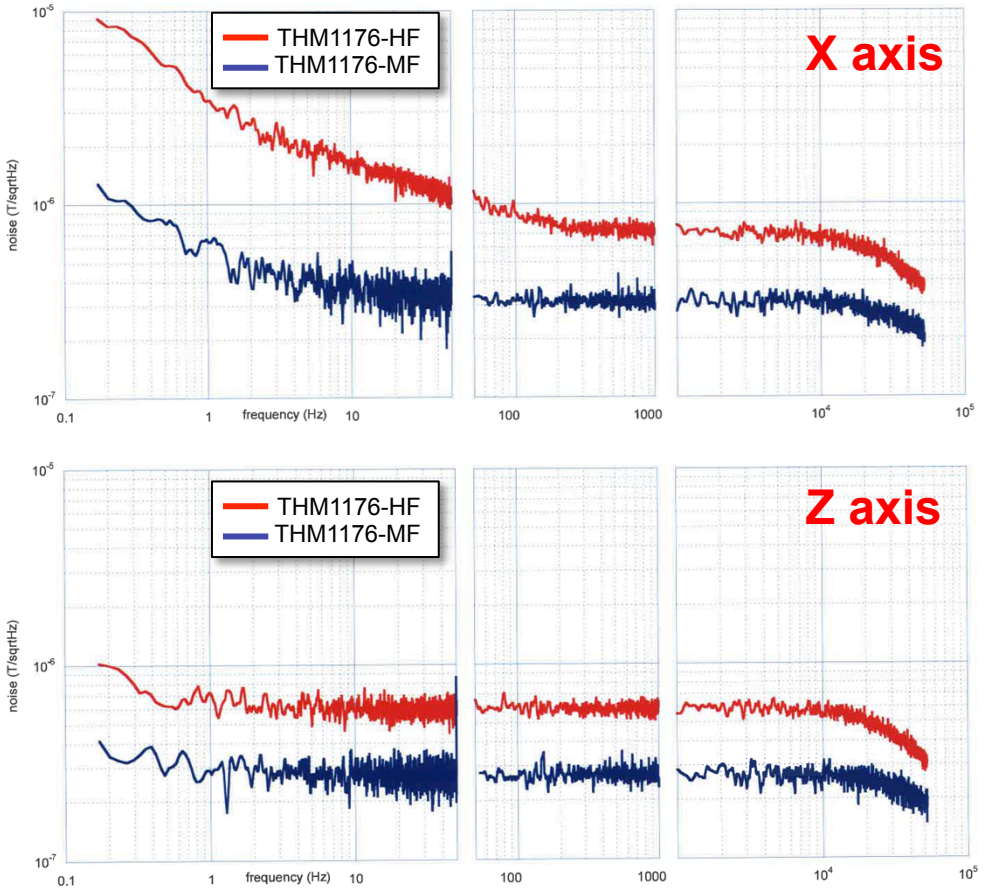
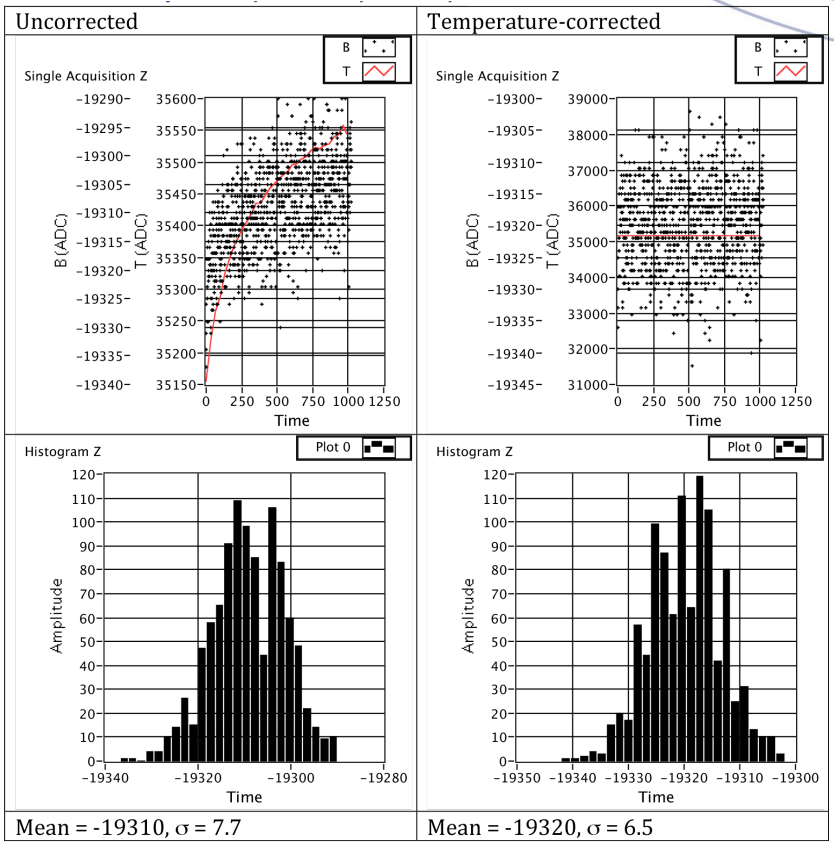
THM1176-MF vs. THM1176-HF

- Lower noise density…
- especially for vertical Hall sensors < 200 Hz
- => Improved resolution – now limited by ADC



Temperature correction

- Self-heating / cooling due to range changes
- More important & much faster than external temperature changes!
- Also: temperature dependence is non-linear
- => Rethink firmware temperature correction



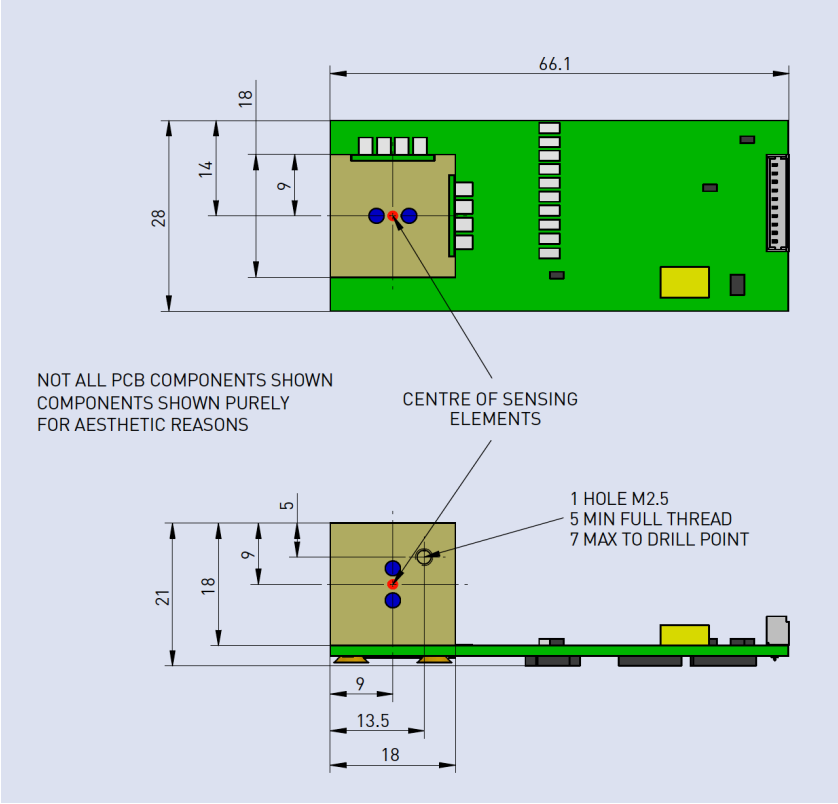
TFM1186

- Bartington Mag649: 3-axis, common origin, low power, 1 kHz bandwidth
- Sensor size: 30 x 32 x 70 mm
- Range: 100 µT
- Resolution: 4 nT
- => Portable instrument to measure “zero-field” disturbances

TFM1186: special considerations

No temperature sensor:

- Electronics calibrated by Metrolab, sensor by Bartington
- => Accuracy specs:
  - Offset: ±100 nT
    1 nT/°C
  - Scale: ±0.5%,
    100 ppm/°C
- => Sensor connector



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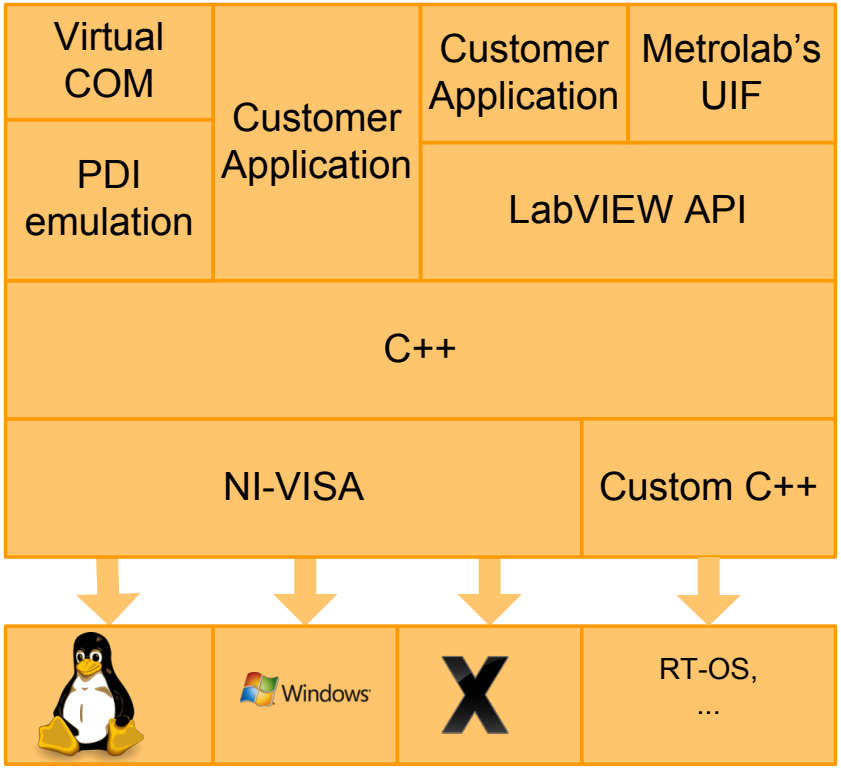
FDI2056: Fast Digital Integrator Status at IMMW17

- History:
  - 2008: License from CERN
  - 2009-2010: Shipments
  - 2010-2012: Major upgrade
  - 2012/2013: Shipments resume
- Limitations of original design:
  - External trigger only
  - Time lag when daisy-chained
  - 2^n-1 partial integrals only
  - 50 ns trigger time resolution
  - Trigger rate < ~100 kPI/s
  - No voltage acquisition option
  - Not field-upgradable
- Firmware bugs:
  - Odd saw-tooth pattern
  - Sampling rate affects result
  - Fast trigger causes calculation error
  - No buffer overflow error reporting
- Metrolab upgrade:
  - Position encoder input per channel
  - On-board memory (1 MPI)
  - “Trigger factory”
  - Single clock / crate
  - Channel synchronization < 1 ns
  - Trigger rate to 500 kPI/s
  - Beatings due to multiple clocks
  - Nonlinearity due to protection diode
  - Field-upgradability
- Limitations that remain:
  - Input is not floating
  - Not fully EMC compliant
  - Non-negligible input impedance
  - R(coil) ignored in auto-calibration
  - Maximum gain is 100x
  - Slow data transfer (1-1.2 MB/s)

FDI2056: Interface

- Proposed at IMMW17:



- Solution retained:
  - Industrial Windows computer in PXI crate
  - Preinstalled app => "out of box" operation
  - Or => Ethernet interface:
    - VXI-11 / SCPI standards
    - LabVIEW driver on National Instruments' web site
    - All source code
  - Or => Serial interface:
    - PDI5025 compatibility
  - Lower crate system cost!

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FDI2056: Key specifications

- Gain: 0.1 – 100
- Range: ±10 V ÷ Gain
- Timer resolution: 12.5 ns
- Noise floor (1kHz BW): -103 dB (gain 0.1-10), < -97 dB (other)
- Harmonic distortion: ~ -105 dBc
- Max offset variation: < Noise floor ÷ 5
- Trigger sources: External, Timer, Encoder, Software, Multi-channel
- Rate: 0.02 Hz – 500 kHz
- Channels: 1-3

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FDI2056: at Danfysik

- Large-aperture rotating-coil measurement system
- End customer: Raja Ramanna Centre for Advanced Technology (RRCAT) in Indore, India
- 5 coils, 2 m long x 64-276 mm diameter
- Glued into 2.5 m long coil tubes with cross structure
- Includes automated magnet alignment system, DCCTs for current measurement, 6-axis measurement arm
- FDI2056 in PDI5025 emulation mode, for compatibility with existing software

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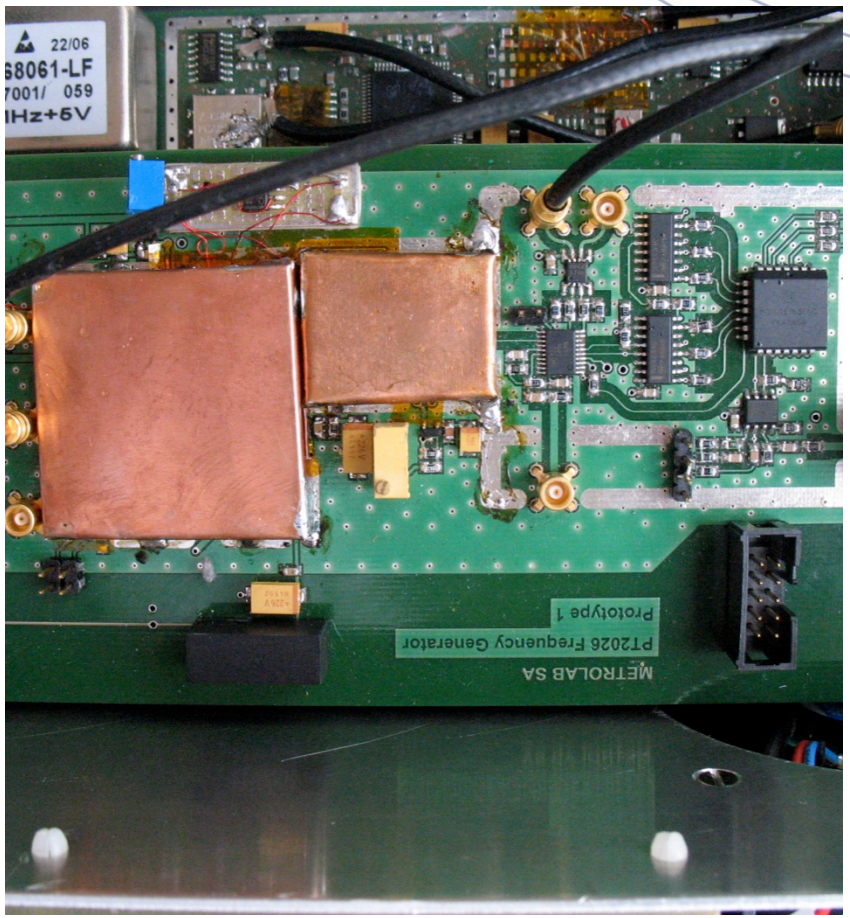
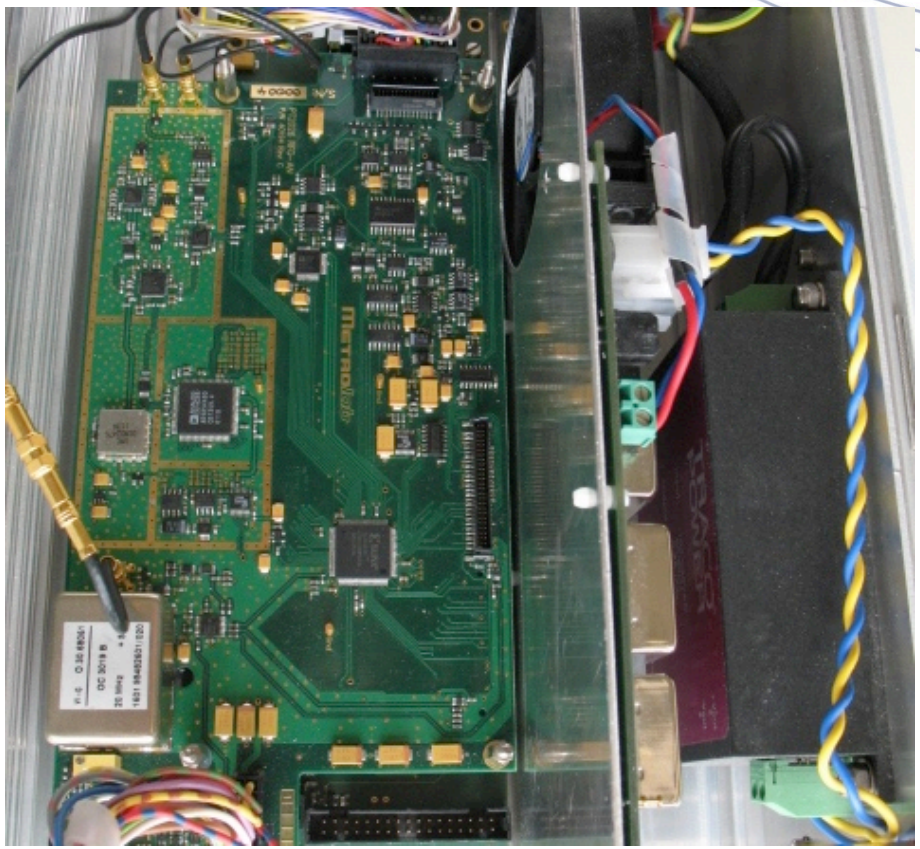
PT2026: NMR Precision Teslameter

- History:
  - 2003 Project launch
  - 2006 Failed market introduction
  - 2009 Last update at IMMW16
  - 2013 Project completion???
- Technical issues:
  - Beat frequencies due to DDS:
    → False NMR signals
  - Frequency modulation:
    → Sloping base line => signal extraction difficult
    → Existing probes not designed for it
  - Auto-tuning of CW probes:
    → Digital approach: noise sensitivity => high-res DAC, computationally intensive
    → Analog approach: destabilized by beat frequencies
- => New approach



PT2026 “version 2.1”: scope

- Pulsed-wave probes
- 1 channel + external mux
- Ethernet & USB:
  IEEE 488.2, SCPI protocols
- LabVIEW application & API
- Later:
  - New continuous-wave probes (low field)
  - Adapter for PT2025 probes
  - Front panel
  - Multi-probe systems (“Magnetic Field Camera”)
  - Flowing-liquid for very wide-range single probe



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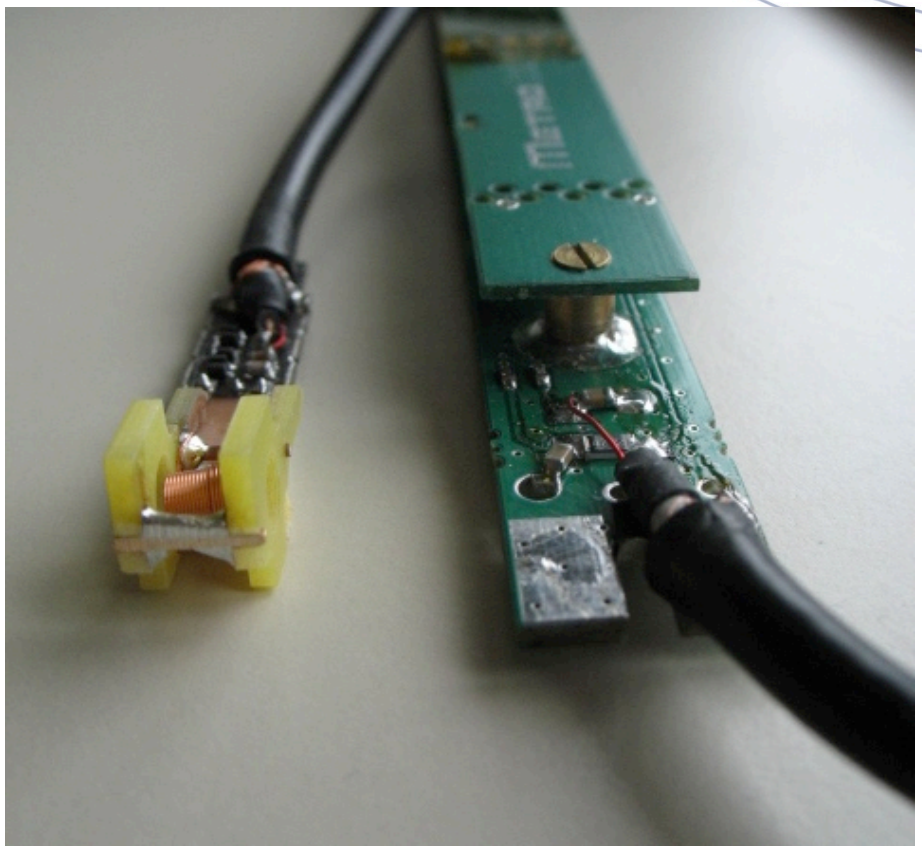
PT2026 v2.1: Benefits over PT2025

- High frequency => high fields
- Pulsed-wave => accuracy
- Flexible RF generator =>
  flexible field ranges
- Built-in 3-axis Hall probe => fast search
- Signal processing =>
  inhomogeneous-field performance
- Flexible parameters =>
  trade off accuracy vs. measurement rate
- Remote sample coil =>
  small gaps, high radiation
- No field modulation =>
  multiple probes in same field
- Trigger in/out =>
  measurement system integration
- Reference clock input => no calibration
- Standard interfaces, LabVIEW software
  => “install & plug & play” with computer

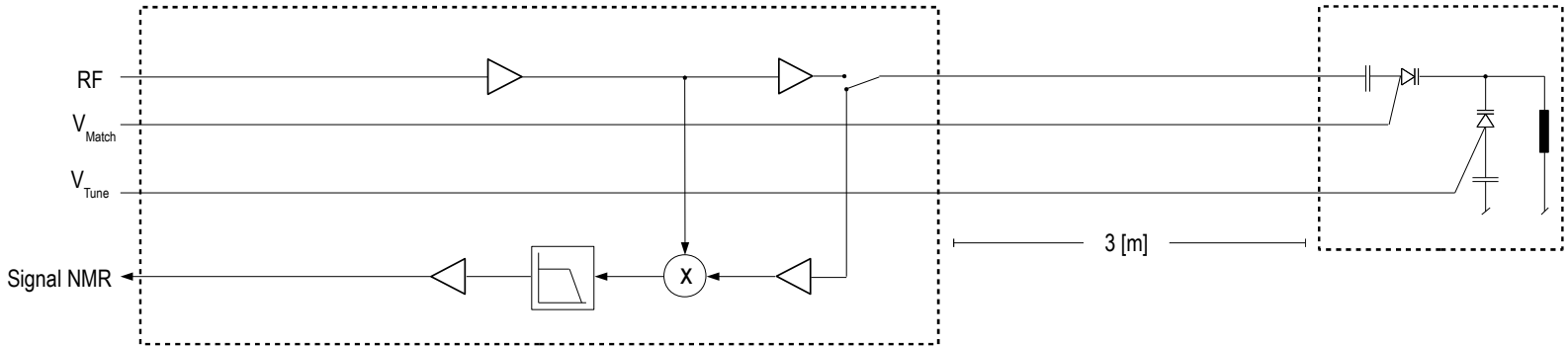
PT2026 v2.1: Limitations

- Current probe design:
  - ~8 – 500 MHz
    => 0.2 – 12 T with H
    => 1.2 – 76 T with ^{2}H
- High frequency derivative in (near) future:
  - – 1.1 GHz
    => – 26 T with H
    => – 168 T with ^{2}H
- Low frequency derivative?
  - Alternative is new CW probe:
    => Prototype available
    => Requires CW upgrade
    => Down to ~ 40 mT with H



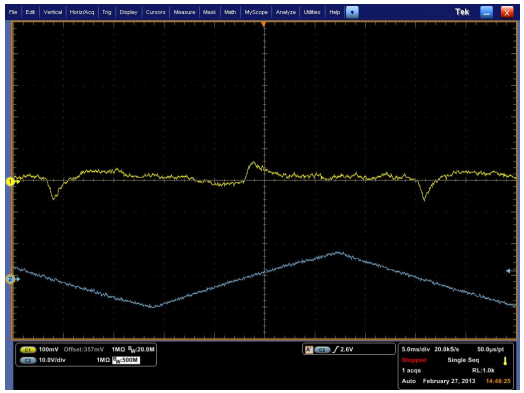
PT2026: inhomogeneous fields

- Compare in field of 0.99T (42 MHz), plus gradient coil:
  - PT2025 & 1062-4
  - PT2026 “SF” (“Single-Frequency” = same frequency for transmit pulse & IF mixing – version 2.1)
  - PT2026 “DF” (“Dual-Frequency” = separate frequencies for transmit pulse & IF mixing – future upgrade)

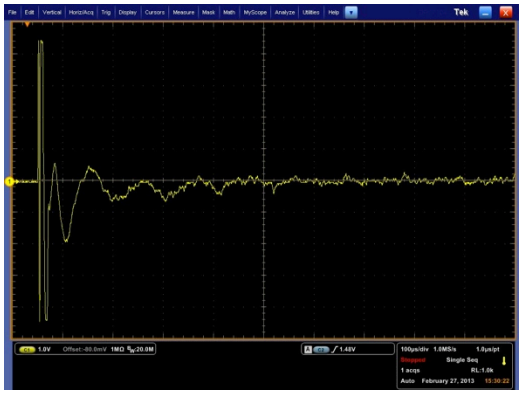


PT2026: inhomogeneous fields

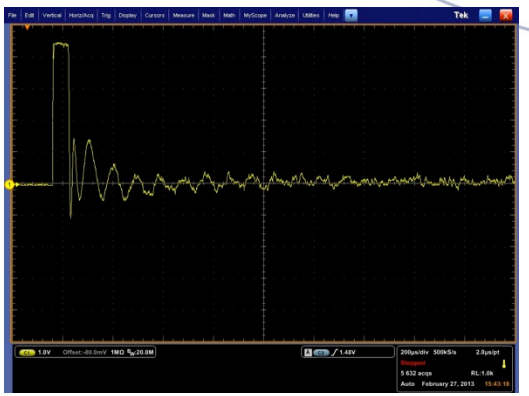
Gradient coil: 0.6 A (est. 810 ppm/cm)



PT2025



PT2026 SF



PT2026 DF

	PT2025	PT2026 SF	PT2026 DF
Max gradient: search & measure	0.4 A (540 ppm/cm)	0.6 A (810 ppm/cm)	1 A (1350 ppm/cm)
Max gradient: measure	0.5 A (675 ppm/cm)	0.75 A (1012 ppm/cm)	1.2 A (1620 ppm/cm)

Questions?