HDice Review

Peter Bonneau
Detector Support Group

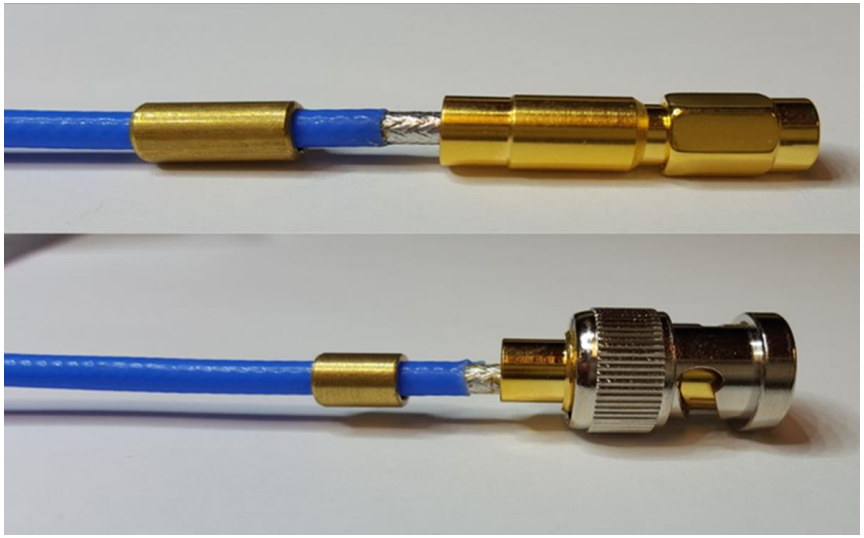
Detector Support Group

1. Search for semi-flexible NMR cables with low loss or controlled temperature variation.

   Status: **Completed**.

- Conducted extensive research due to requirements
- Selected *Molex Temp-Flex Air-Dielectric Ultra-Low-Loss Flexible Microwave Coaxial Cable*
- Ordered and received 1,500 feet of cable

- Designed three types of low-cost connector adapters
  - SMA plug
  - “N” type plug and BNC plug
  - “N” type jack

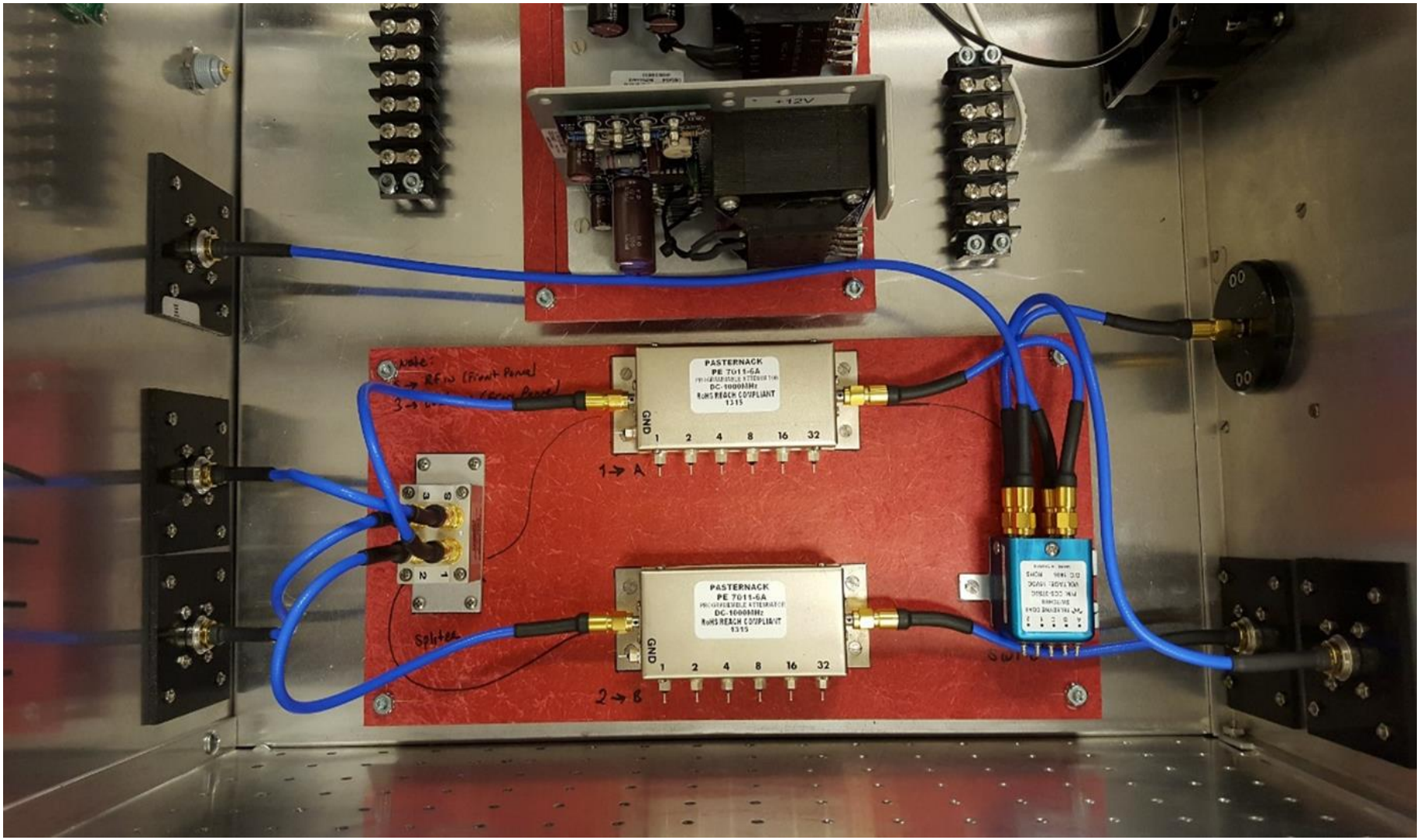


SMA (top) and BNC (bottom) cable adapters

- Developed assembly techniques and adapter insertion procedures

- Fabricated cables
  - Prototypes
    - Refined assembly techniques
    - Tested cable performance
  - Rack inter-connect cables
    - RF signal generator
    - RF Attenuation/Switching Unit
    - Lock-in amplifier
    - RF amplifier
  - Test cables in cryostats
  - Internal RF cables
    - 2^{nd} and 3^{rd} RF Attenuation/Switching Unit
      - For 2 attenuators, splitter, and connections to the front and rear panels

“N” type plug fabrication steps



Fabricated RF cables installed in the RF Attenuation/Switching Unit

2. Construct (2) sets of dual cables with lengths adjusted to operate on λ/2 resonance with tuned NMR circuit (R_L C_L)

Status: **Incomplete**

- Waiting on length information

3. Install a precision (temperature – stabilized) shunt to directly read current from Oxford supplies that drive the magnets used for NMR – one shunt for each NMR rack.

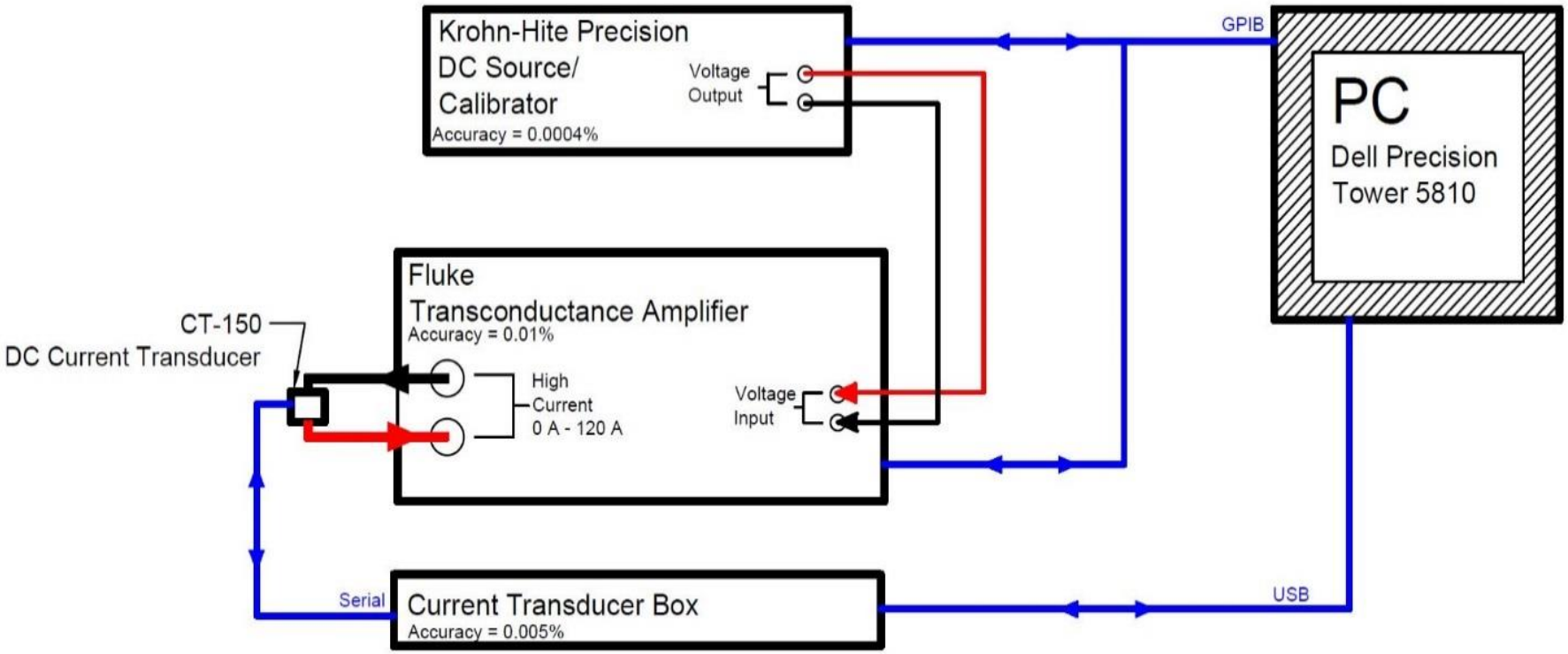
Status: **Incomplete**

- Procured one CAENels CT-BOX
  - After extensive research of precision current measurement systems
- Procurement of 2nd CT-BOX is pending approval

- Summary of CT-BOX (shunt) specifications
  - Range +/- 150 A
  - ADC current resolution 24 bit
  - Current accuracy < 0.005%
  - Sampling frequency 0.1 Hz – 100 KHz
    - Data logger mode (0.1 Hz – 10 Hz in 0.1 Hz steps)
    - Oscilloscope mode (1.0 Hz – 100 KHz)
  - Time range (10^6 µs–10 µs in 10 µs steps)
  - Built-in temperature compensation
    - Thermal coefficient < 1 ppm/K
  - Integral power supply and local readback display
  - Multiple communication interfaces
    - USB, RS232, and Ethernet

- New product by CAENels (delivery time >15 weeks)
- Many new product issues
  - Firmware errors requiring updates
  - Hardware issues
  - Lack of documentation on software protocols
  - Not shipped with software
  - Required extensive development of library of LabVIEW instrument device driver functions (~ 50 subVIs)

- Developed LabVIEW DAq code using the device driver library functions to test the CT-BOX
- Incorporated library of device driver functions and DAq code in NMR program
- Completed calibration system for current measurements



Calibration test setup of the CAENels CT-BOX

DSG Note 2016-008 https://www.jlab.org/div_dept/physics_division/dsg/notes

CAENels CT-BOX Calibration Procedure

- Used Krohn-Hite and Fluke drivers to set a demand current to be read at CT-BOX (I_{set})
- Used CT-BOX drivers to measure actual current at CT-BOX ($I_{Meas.}$)
- Covered range of 0 A – 25 A with 1 A step- size
  - Took 1000 measurements at each step

CAENels CT-BOX Calibration Results

- Linear Fit: $I_{Meas} = 0.99996\, I_{Set} + 0.00222$
- For large I_{Set}, I_{Meas} $\mathrm{Error} \rightarrow 0.003\%$
- Combined with input accuracy, can measure to 0.0104% accuracy

4. Update existing NMR analysis codes to the newest version of Mathematica. (e.g. Version 5 to version 8, or the most recent Jlab supported version).

- General Polarization Data Analysis Package June 2008.nb
- Inductance Jlab Target Reference.nb
- Inductance LEGS Target Reference.nb
- Parameters from Resonance Curves v1.nb
- RF Birdcage Coils.nb
- KK transformation-Craig.nb
- Polarized Lineshape Analysis v1.nb

Status: **Incomplete**

- Information required from BNL not available

5. As a Debug/Test exercise, take resonance scan data (with HDice help), run programs and fit the resonance curve to deduce circuit parameters.

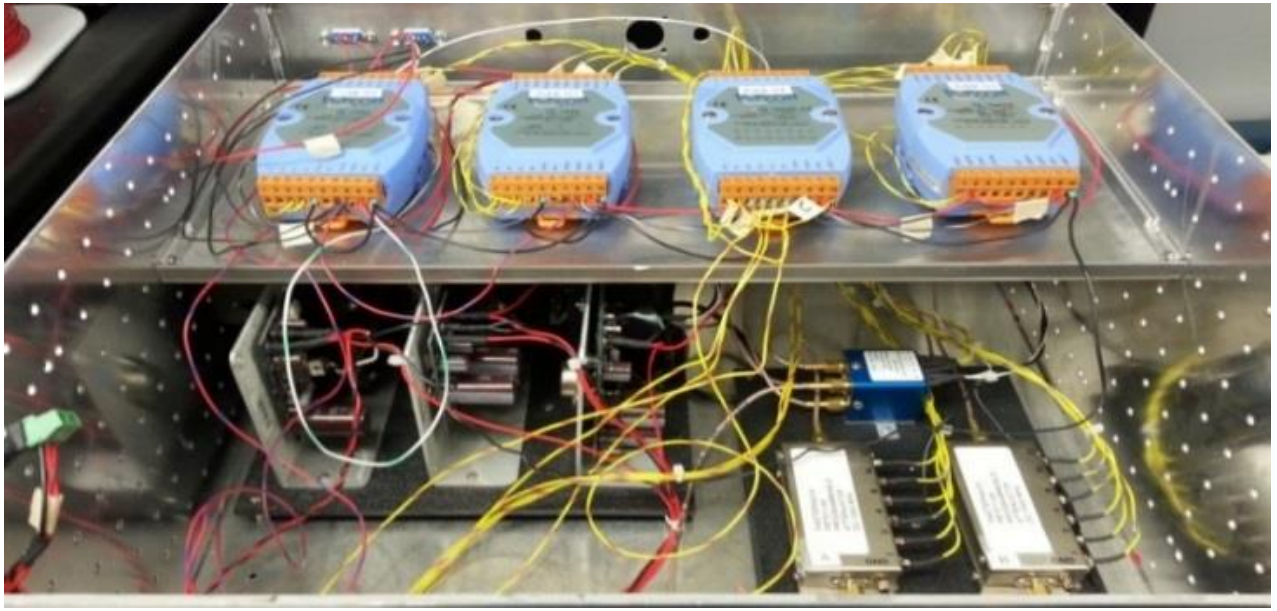
Status: Incomplete

- Completion of the Mathematica upgrade necessary before this task can be started

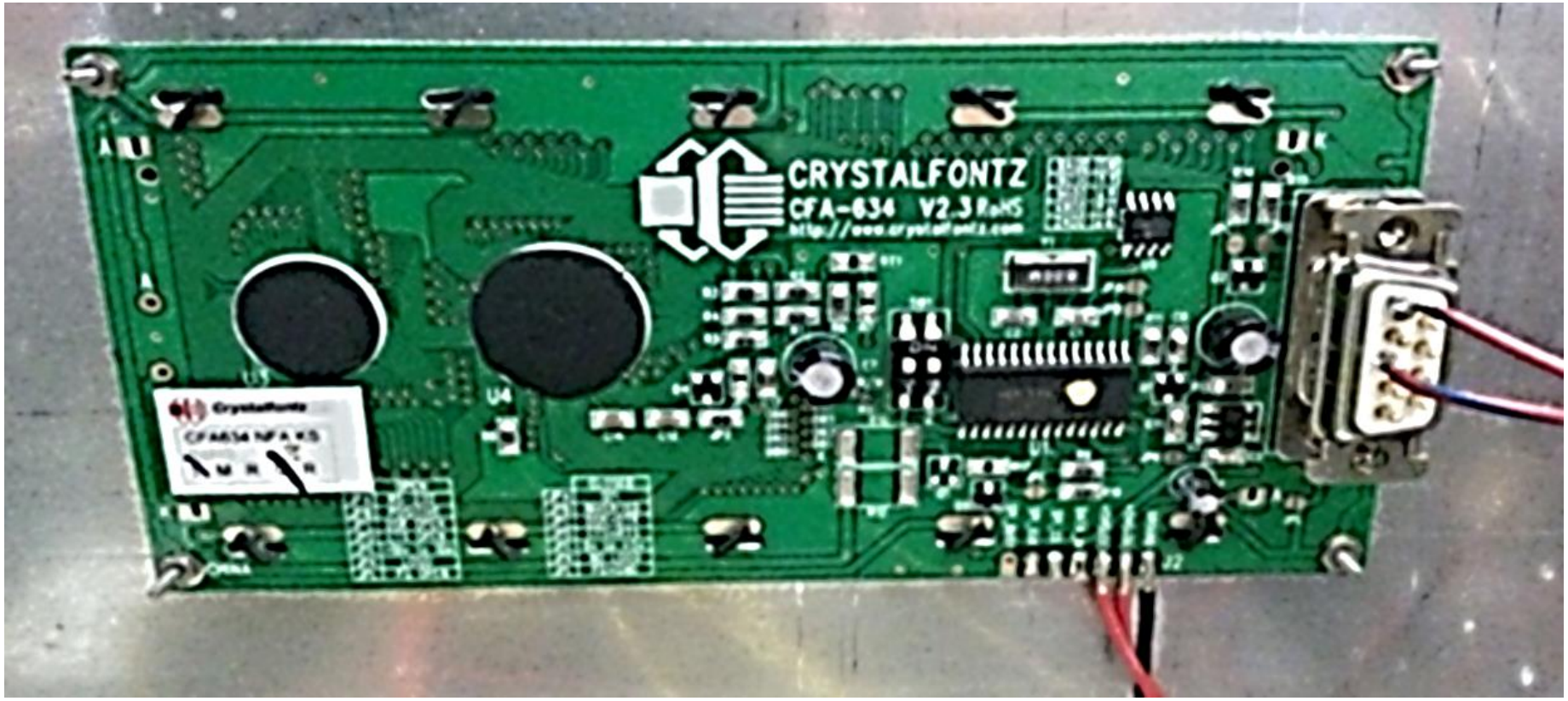
6. Upgrade RF distribution and attenuation control to display current settings on attenuator box and integrate into NMR control codes so that changes are reflected in display.

Status: **Completed**

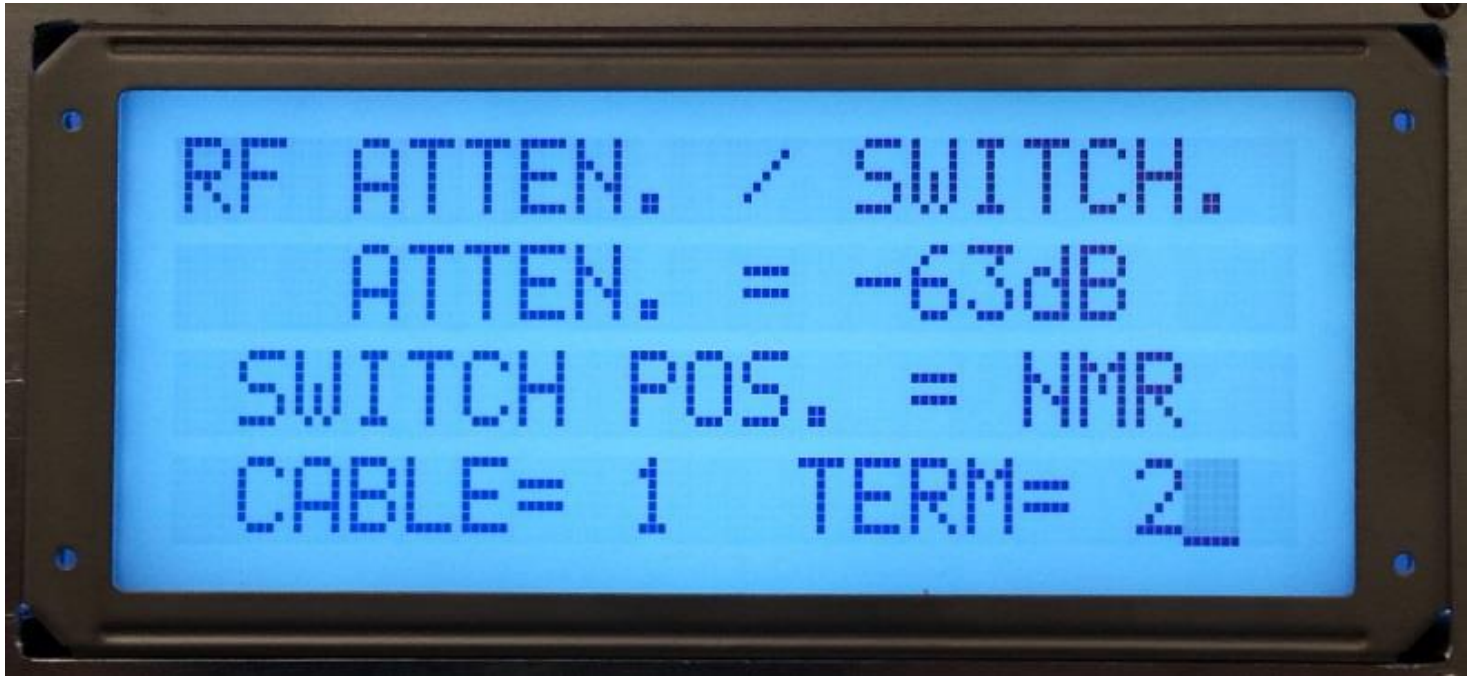
- Redesigned, rewired, and tested RF Attenuation /Switching Unit's hardware DAq modules' connections



- Replaced peripheral interface controller board with a simplified direct communication connection to RS232 interface



- Developed, debugged, and tested
  - Device drivers for front panel display interface
  - subVIs to read settings



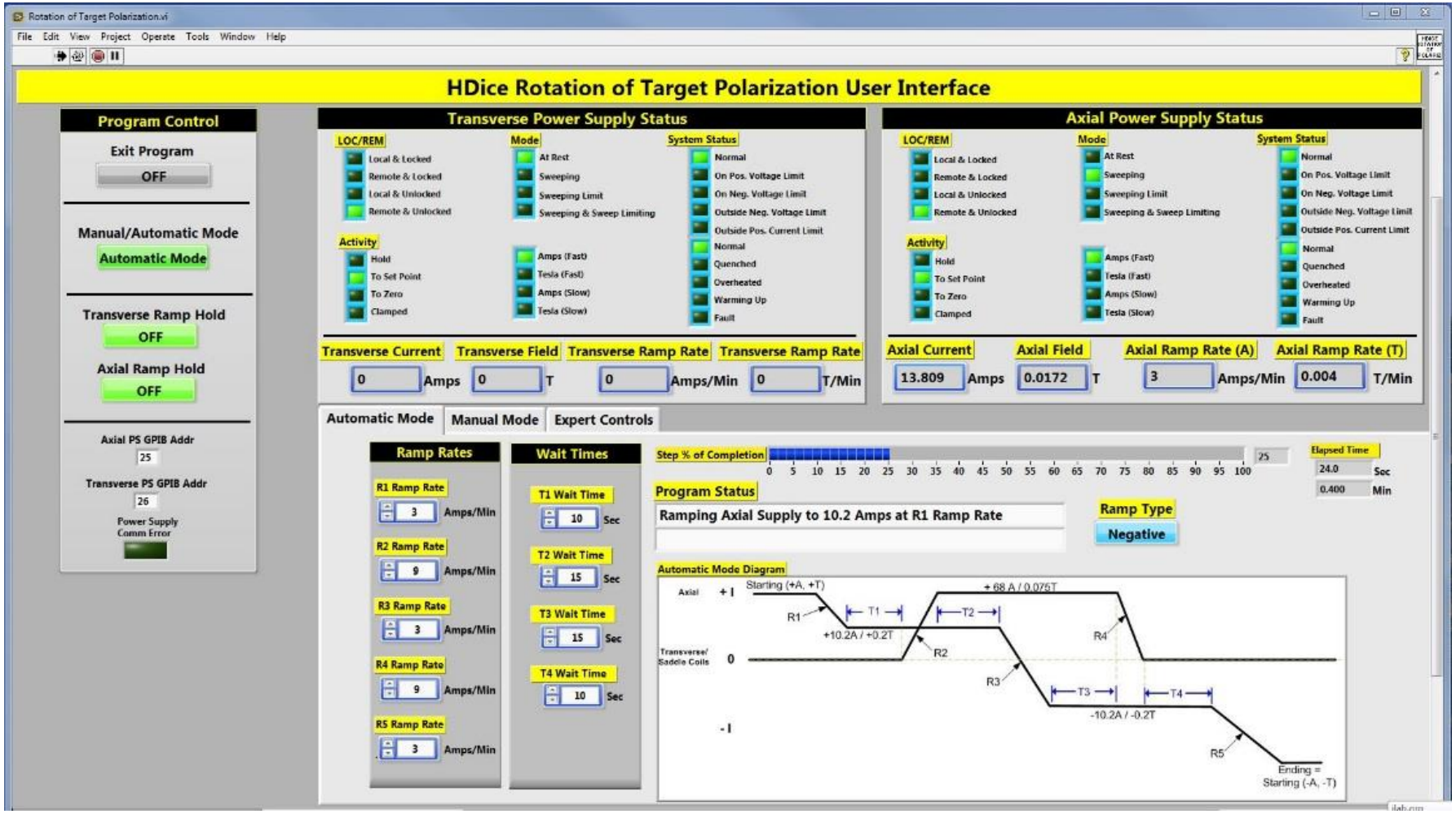
Front panel display

7. Write a program to control 2 power supplies to rotate HDice target polarizations (by varying currents in both solenoid and saddle coils).

Status: **Completed**

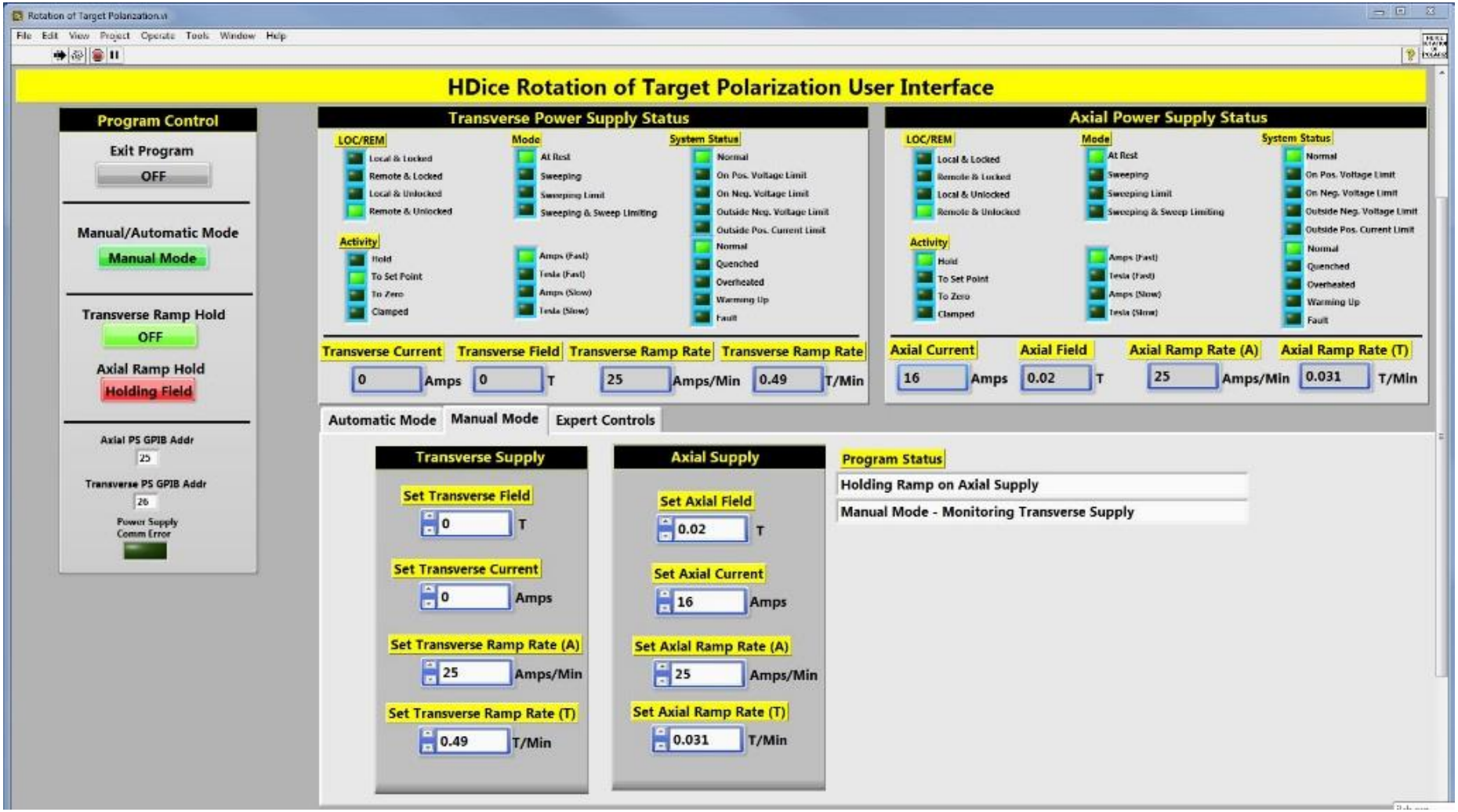
- Developed, debugged, and tested LabVIEW code for
  - Rotation of target polarizations
  - Manual control option upon completion of automatic rotation
  - Simultaneous ramping of both axial supply and transverse supply during manual mode operation
  - Ramp-hold function
- Updated Oxford power supply device drivers to LabVIEW 2015
- Demonstrated operation of completed program

- In Automatic mode
  - Ramp rates and wait times set by operator at program start
  - Program status displayed continuously
  - Progress of rotation shown by indicator
  - Power supply set-points, readbacks, and status for both axial and transverse updated continuously
  - Hold (pause ramping) feature available during rotation



Automatic Mode

- In Manual mode
  - Operator can choose to set current, field, and ramp rates for both supplies
  - program status displays continuously
  - Power supply set-points, readbacks, and status for both axial and transverse updated continuously
  - Hold (pause ramping) feature available
    - The axial supply is holding in LabVIEW front panel screen shown next


Rotation of Target Polarization.vi
File Edit View Project Operate Tools Window Help
HDice Rotation of Target Polarization User Interface
Program Control
Exit Program
OFF
Manual/Automatic Mode
Manual Mode
Transverse Ramp Hold
OFF
Axial Ramp Hold
Holding Field
Axial PS GPIB Addr
25
Transverse PS GPIB Addr
26
Power Supply Comm Error
Transverse Power Supply Status
LOC/REM
Local & Locked
Remote & Locked
Local & Unlocked
Remote & Unlocked
Mode
At Rest
Sweeping
Sweeping Limit
Sweeping & Sweep Limiting
System Status
Normal
On Pos. Voltage Limit
On Neg. Voltage Limit
Outside Neg. Voltage Limit
Outside Pos. Current Limit
Normal
Quenched
Overheated
Warming Up
Fault
Activity
Hold
To Set Point
To Zero
Clamped
Amps (Fast)
Tesla (Fast)
Amps (Slow)
Tesla (Slow)
Transverse Current
0
Amps
Transverse Field
0
T
Transverse Ramp Rate
25
Amps/Min
Transverse Ramp Rate
0.49
T/Min
Axial Power Supply Status
LOC/REM
Local & Locked
Remote & Locked
Local & Unlocked
Remote & Unlocked
Mode
At Rest
Sweeping
Sweeping Limit
Sweeping & Sweep Limiting
System Status
Normal
On Pos. Voltage Limit
On Neg. Voltage Limit
Outside Neg. Voltage Limit
Outside Pos. Current Limit
Normal
Quenched
Overheated
Warming Up
Fault
Activity
Hold
To Set Point
To Zero
Clamped
Amps (Fast)
Tesla (Fast)
Amps (Slow)
Tesla (Slow)
Axial Current
16
Amps
Axial Field
0.02
T
Axial Ramp Rate (A)
25
Amps/Min
Axial Ramp Rate (T)
0.031
T/Min
Automatic Mode
Manual Mode
Expert Controls
Transverse Supply
Set Transverse Field
0
T
Set Transverse Current
0
Amps
Set Transverse Ramp Rate (A)
25
Amps/Min
Set Transverse Ramp Rate (T)
0.49
T/Min
Axial Supply
Set Axial Field
0.02
T
Set Axial Current
16
Amps
Set Axial Ramp Rate (A)
25
Amps/Min
Set Axial Ramp Rate (T)
0.031
T/Min
Program Status
Holding Ramp on Axial Supply
Manual Mode - Monitoring Transverse Supply

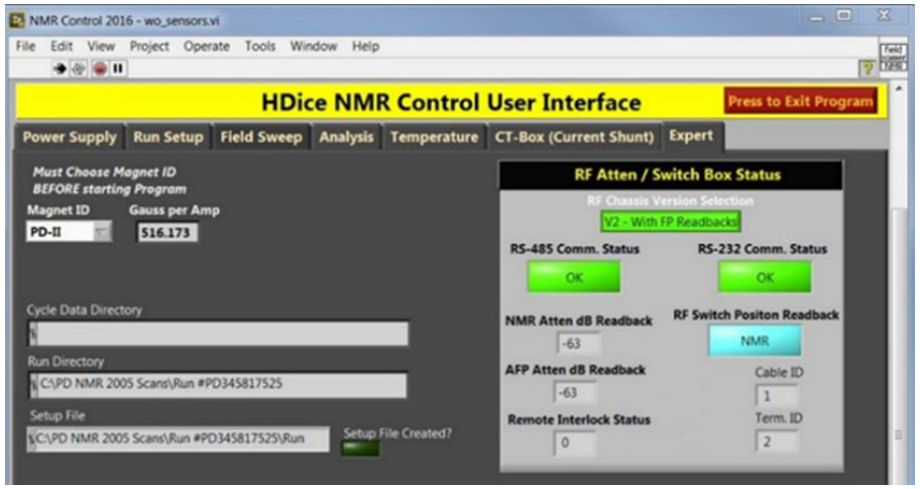
Manual Mode

8. Modify component-ID key portion of the NMR control codes to allow the VI to distinguish between cable types.

Status: **Completed**

- Redesigned interface to RF Attenuation/Switching Unit digital DAq modules for addition of component-ID key reading
- Fabricated:
  - Cable and connector assemblies to connect front panel component-ID keys to DAq modules
  - CPC keys which will ID the various types of cable

- Developed, debugged, and tested
  - SubVIs to initialize, read, and write RF Attenuation /Switching Unit's digital DAq modules for component-ID additions
  - Program to test the component-ID interconnects and connections to the DAq modules and the CPC keys
  - SubVIs have been integrated into the NMR code



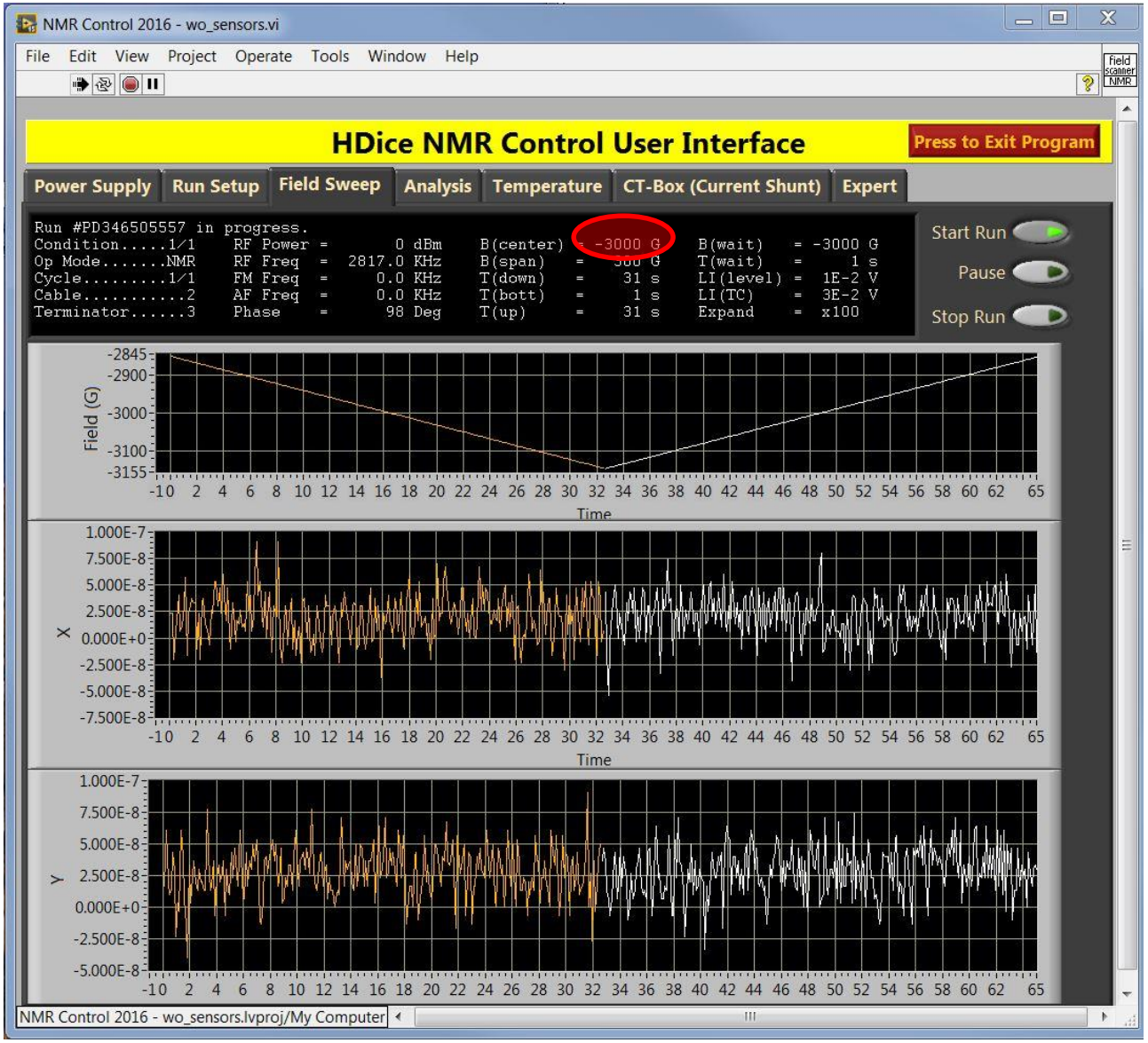
Display of component-ID key readings

CPC component ID keys

9. Modify NMR control program to run NMR scans with both positive and negative current in the magnet power supply.

Status: **Completed**

- Identified, rewrote, debugged, and tested NMR code section that prevented running both positive and negative NMR scans



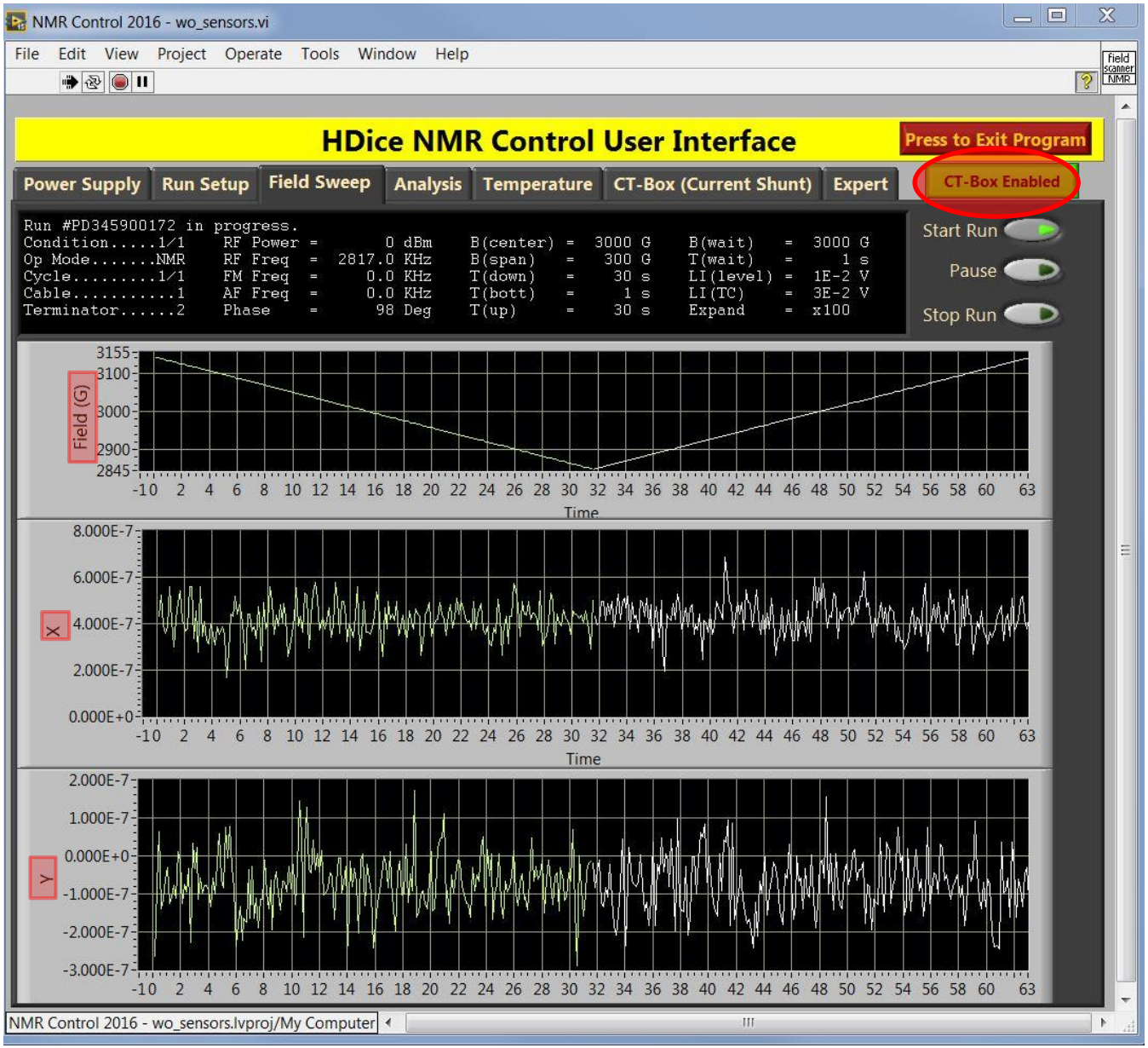
Negative NMR scan centered around –3000 Gauss

10. Incorporate precision shunt into field controls.

Status: **Completed**

- Developed library of LabVIEW instrument device driver functions and DAq code library for the CAENels CT-BOX
  - Integrated software into the NMR program
  - In new NMR program, online field and lock-in amplifier's X-Y data is displayed on front panel and allows online viewing of calculated field using either CT-BOX's current readback or magnetic field readback from power supply

CT-BOX control and status readback tab in NMR program



NMR program scan using CT-BOX current shunt

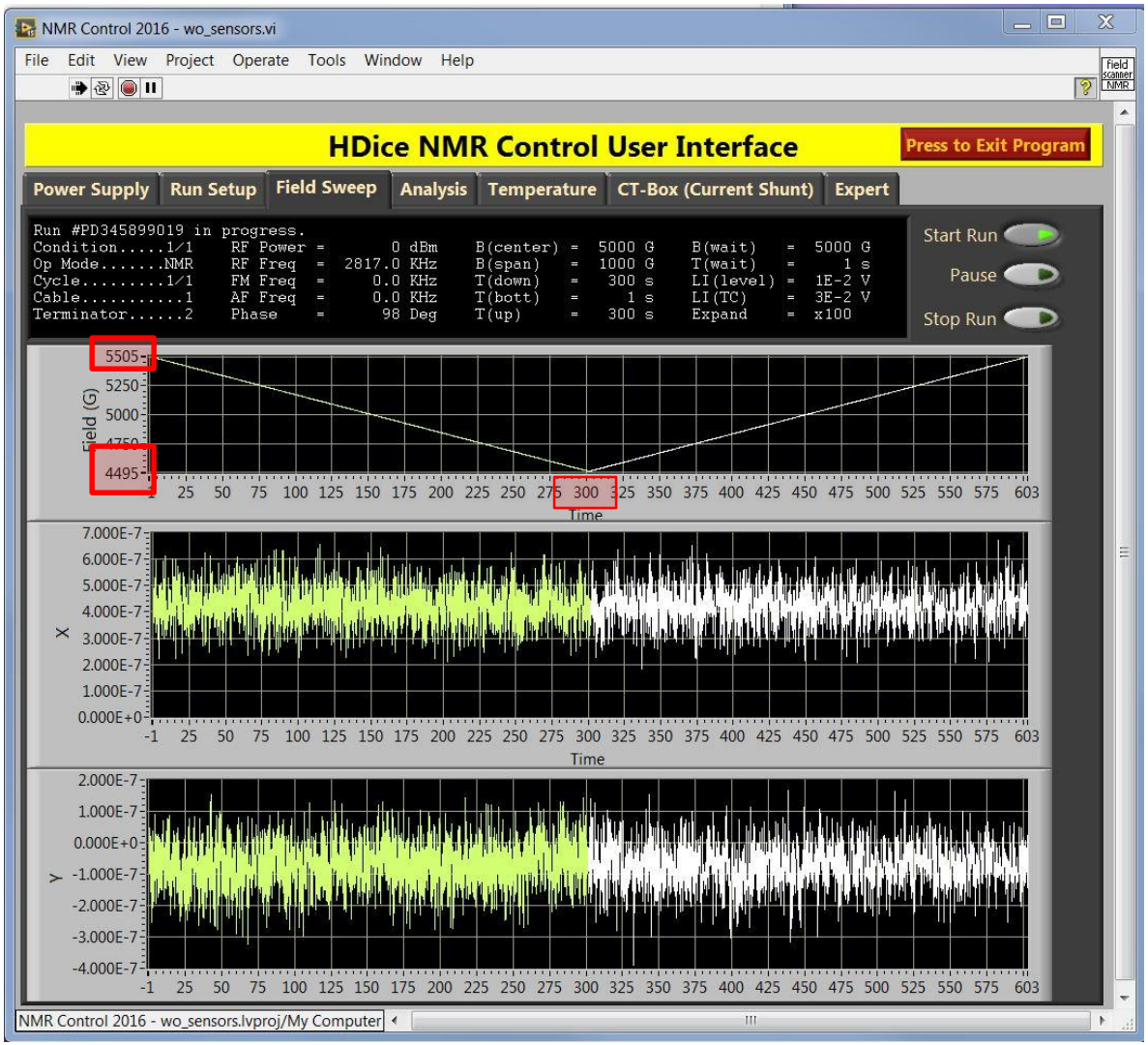
11. Debug and finish existing NMR control codes, eg. NMR field sweep:

Present system is only understandable for tdwn = tup = 31 sec and range = 300 gauss;

Flexibility to change ranges and compare results is needed.

Status: **Completed**

- Programmed, debugged, and tested T(down) = T(up) scan times from 10 s to 300 s
- Extended sweep range (span) to 1000 G
  - Oxford power supply has minimum sweep rate of 0.01 A/min
- Demonstrated capability of running NMR scans with varying sweep times and ranges



NMR scan with T(down) and T(up) = 300 s and 1000 G range

12. Re-activate online noise analysis VI.

Status: **Incomplete**

- Task to be completed during NMR program re-write
  - Code development needs input

Additional work performed

(Not on original task list)

- Upgraded computers to Windows 7
  - Computers had XP installed, no longer supported by Microsoft or JLab Computer Center
- Reconfigured computer settings
  - Win 7 upgrade
  - Request from Computer Center for administrator rights
  - No auto rebooting, and no sleep mode
- Investigation into LabVIEW for Linux
- Hardware and software upgrade was mandatory for RS-485 and RS-232 instrumentation communication hubs

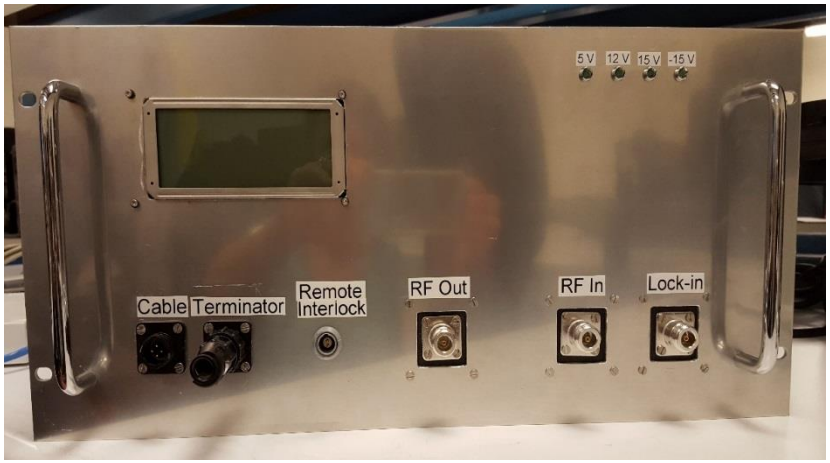
- Development computer died
  - Order new computers
  - Receipt and initial setup of operating system (computer center)
  - Loading of development software (LabVIEW, etc.)
  - Configuration of hardware interfaces (GPIB, RS232, RS485, etc.)
  - Load LabVIEW code
  - Test instrument communication
- Researched current measurement systems better than 0.01% accuracy

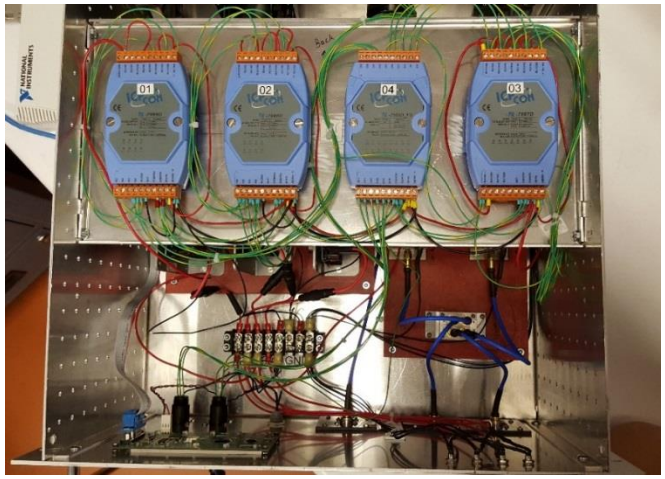
- Updated, debugged, and tested all computer interface instrumentation communication device drivers to LabVIEW 2015
- Upgraded computers to LabVIEW 2015 (JLab site license)
- Developing drivers to have capability of using either original Oxford power supplies or new Oxford Mercury iPS power supplies, which do not have GPIB interface

- Built and relocated test station multiple times

Test station

- Built 3rd RF attenuator/Splitter box





Fabrication 3rd RF Splitter / Attenuator Box.

Conclusion

- Significant contributions by DSG staff in the following areas:
  - R&D
  - Software development
  - Fabrication
  - Test and measurement
  - Installation
  - Safety
- Extensive additional work performed to complete tasks

All tasks under DSG control completed.

Conclusion

- Of 12 tasks
  - 7 completed
  - 5 incomplete
    - Item #2: construct cables to operate on λ/2 resonance
      - Need information
    - Item #3: Instrumentation of 2nd NMR rack with precision shunt
      - Awaiting approval for 2nd CT-BOX
    - Item #4: Upgrade Mathematica version
      - Need information from BNL
    - Item #5: Take resonance scan data
      - Need upgraded version of Mathemetica
    - Item #12: Activate noise analysis
      - Need information

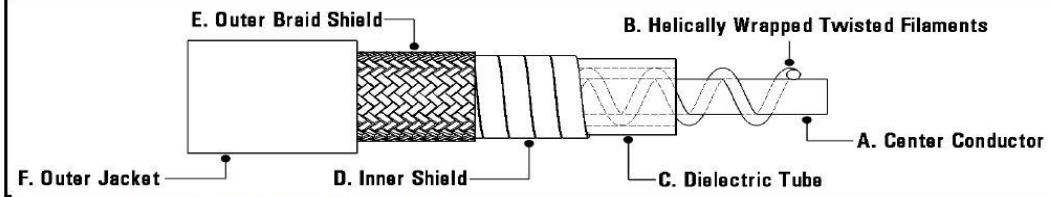

Thank You

Backup

TEMP-FLEX
a molex company

Ultra Low Loss Microwave Coax

Part Number: 141-1701



RoHS COMPLIANT

Construction / Mechanical Specification

Section	Material	Dimensions	
A. Center Conductor	Silver Plated Copper	0.0453 in	1.15 mm
C. Dielectric	FEP (High Purity)	0.1170 in	2.97 mm
D/E. Inner / Outer Shield	Silver Plated Copper	0.1380 in	3.50 mm
F. Outer Jacket	FEP	0.1580 in	4.01 mm

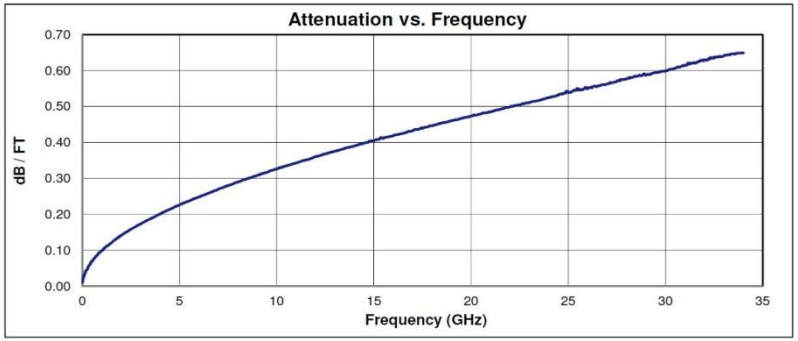
Minimum Static Bend Radius (<0.5Ω)	0.75 in	19.1 mm
Minimum Dynamic Bend Radius	1.50 in	38.2 mm
Cable Weight	24.0 lbs/kft	35.75 kg/km
Operating Temperature	-85ºF - 257ºF	-65ºC - 125ºC
Material Flammability Rating	V-0 (UL 1354)	

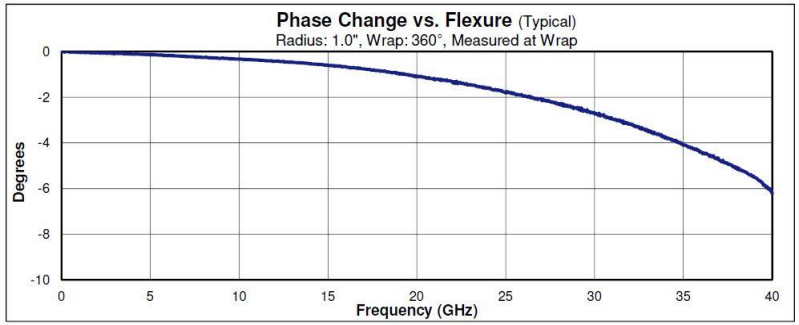
Electrical Specification

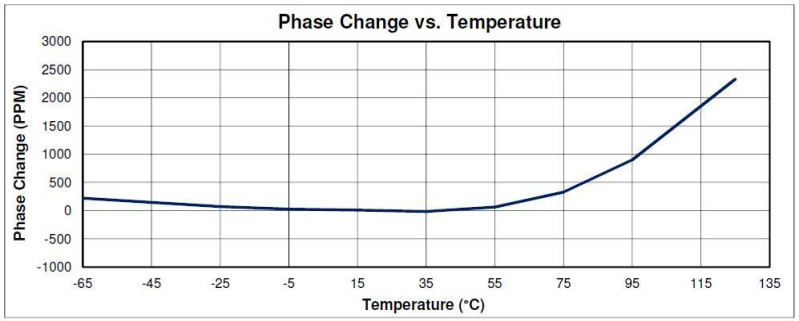
Characteristic Impedance	50 Ω ± 1 Ω	
Propagation Delay	1.165 ± 0.01 ns/ft	3.822 ns/m
Velocity of Propagation	87%	
Capacitance	23.3 pF/ft	76.4 pF/m
Cut off Frequency	41 GHz	
Shielding Effectiveness	>100 dB	
VSWR (DC - 40 GHz)	1.20 Max.	

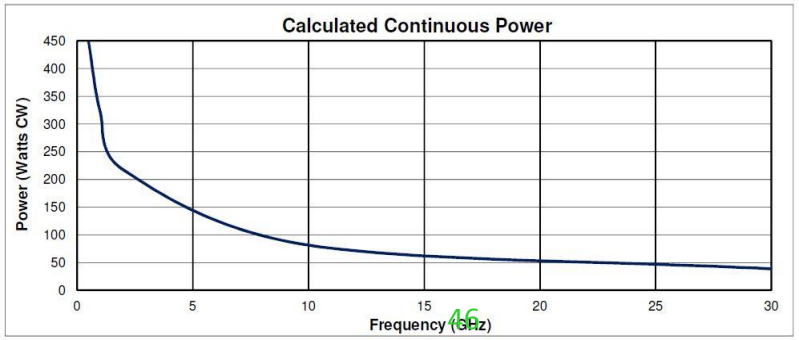
Attenuation vs. Frequency

Frequency (GHz)	(dB / ft)	(dB / m)
1	0.08	0.28
4	0.18	0.59
6	0.25	0.82
12	0.34	1.12
18	0.43	1.41
26	0.54	1.78
34	0.64	2.10
40	0.73	2.40


Attenuation vs. Frequency
dB / FT
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
0
5
10
15
20
25
30
35
Frequency (GHz)


Phase Change vs. Flexure (Typical)
Radius: 1.0", Wrap: 360°, Measured at Wrap
Degrees
0
-2
-4
-6
-8
-10
0
5
10
15
20
25
30
35
40
Frequency (GHz)


Phase Change vs. Temperature
Phase Change (PPM)
3000
2500
2000
1500
1000
500
0
-500
-1000
-65
-45
-25
-5
15
35
55
75
95
115
135
Temperature (°C)


Calculated Continuous Power
Power (Watts CW)
450
400
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30
Frequency (GHz)