Arecibo 12m Antenna Cryogenic Wideband Front-End

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Cryogenic Front-End Assembly and Start up Procedure

Cryogenic Front-End Assembly and Start up Procedure Part 1

- Carefully Unpack hardware particularly paying to attention to: Cryostat bottom plate holding cold head, RF and DC connectors, vacuum ports, gauge…
- Remove metal plate used to protect the window
- Install Radome: Install the red Silicon Oring on groove on the windows assembly + Mylar Radome + #10-32 screws
- Remove "Short" connector from DC port (Short used to protect electronics from ESD during shipping)
- Connect MC system Cryo Harness to DC port of front end
- Connect the provided Ethernet cable to the MC enclosure RJ45 port on one end and to the Vacuum gauge on the other end
- Thread fiber TX and RX lines into the cable gland of the MC system and connect them to the RJ45 to fiber converter
- Connect power cord of MC to 120V AC
- All power supplies and sub assemblies of the MC are now powered.
- Make sure labjack and fiber link adapter LEDS are ON (including link status LEDs of the media converter)
- Check Voltages by connecting a DMM to the MC test points (labeled):
- Temp1 and Temp2 voltages (voltages across lakeshore silicon diode Part# DT-470) should read ~0.520 V at room temperature
- Vac: Should read ~10V at Pressure =1atm
- POLX LNA: Vg1=-0.16V , VD = 1.77V , ID= 0.352V (Equivalent to: 35.2mA): 10mV / 1mA scaling
- POLY LNA: Vg1=-0.11V , VD = 1.81V , ID= 0.342V (Equivalent to: 34.2mA): 10mV / 1mA scaling
- Note: during cooldown these LNA voltages will not change, the current ID will drop to ~28mA when temperature reaches 20K and lower.
- Run the provided python code on a computer(Linux or windows) after installing the labjack drivers and python library which can be found here: https://labjack.com/support/software/examples/ljm/python
- Labjack has static IP address: 192.168.1.200 , it can be changed to another address or to DHCP (easiest way to do this is the Kipling software provided for free by labjack: and can be found here: https://labjack.com/pages/support?doc=/software-driver/labjack-applications/kipling/
- Make sure the numbers displayed on the terminal agree (within 1-2mV) to the voltages measured with a DMM on test points. The code will also save data in a text file.
- Next: Turn on Vacuum + cryogenics

Cryogenic Front-End Assembly and Start up Procedure Part2

- Connect M125 compressor helium lines and power cord to cold head
- Connect a vacuum pump hose to the valve (make sure the valve is fully closed): The valve has a standard KF/NW25 vacuum port
- Turn on roughing pump and open valve very slowly
- (There is a lot of insulation inside the front end to bring it to lowest temp, opening the valve abruptly might cause damage to insulation)
- Observe the pressure gauge readings on the terminal: voltage will start dropping 10V and pressure will come down from 1atm = 680 Torr slowly.
- When pressure is ~10^-2 Torr or lower (if you use a turbo pump), turn on compressor.
- Observe temperature dropping (voltage across temp sensors increasing)
- It will take ~8-10 hours to cool from 300K to < 20K
- The Drain currents of the 2 LNA will drop very slowly from ~35mA at 300K to ~ 28mA at 20K and lower.

Cryogenic Front-End Assembly and Start up Procedure Part3

- When Temp1 <20K and Temp2(heat shield) < 80K, RF measurements can be done
- Connect Rf outputs labeled: Xout and Yout to RF enclosure X and Y with the provided 6ft cables
- Connect Spectrum Analyzer to RF enclosure output with short cables (1-2ft)
- Make sure there is no moisture on the vacuum window (moisture will add attenuation)
- Spectrum Analyzer (Filedfox N9916A) Settings: (Same as used during Phase 1):
  - 1-12GHz , 201 points
  - Preamp ON (turn it off if “ADC overload” seen.
  - RBW= 1MHz
  - VBW= 100 KHz
  - DETECTOR Mode:Average
  - Trace mode: CLRW
  - RF Atten = 0dB
  - Reference level (-40 or -50dBm) at 5dB /div
  - Averaging factor: 16 sweep
  - (I have python code I used set the Filedfox and collect data , they can provided if needed)

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Technical Notes

Miscellaneous Notes

- Front end vacuum chamber will NOT be under vacuum during shipping (P=1atm). Vacuum valve will be fully closed for protection.
- Cryogenic Front end Window is installed but not the radome
- Radome material (Mylar) + Radome Ring + Oring are included in the shipment (Radome ring needs 6 x Screws #10-32 Length = ¼")
- 2 Radomes will be delivered: One flat , one convex shaped.
- Window will be covered with a metal plate for protection during shipping. Remove 4 x 3/8-16 Bolts
- 4 x "Mounting Leg" will be shipped with the front end to help hold it "up right" During "on ground" testing. They will need to be removed later before installing the front end on the telescope
- Cold head custom fittings will be shipped back to AO
- RF Ports: 4 x SMAs (Female) are labeled (Xout, Xcal, Yout, Ycal) on the flange .
- 4 Connector Savers are mounted (SMA M-F adapters) to protect vacuum connectors, keep them there to protect and reduce wear on those hemertic/vacuum SMA connectors. All 4 RF ports are terminated with 50 ohm load during shipping.
- DC Connector terminated with a "short" for ESD protection during shipping and handling. Will need to be removed before connecting to M&C.
- POLX and POLY LNAs (LNAs SN 2195D and 2192D respectively) have ~3dB difference in gain. This is normal (unit to unit repeatability of LNAs). To make the LNAs "gain matched" add 3dB pad at the output of the POLX LNA (3dB pad at room temp, outside cryostat, can be inside Rf enclosure if preferred)
- All 4 RF ports have connector savors, DC cryo harness is made of 5 shielded cables each shield is connected to the "drain" wire which is connected to the cryostat metal on one end and to the earth ground inside the MC enclosure.

Miscellaneous Notes (Continued)

- Additional 10dB Pad installed on coupled port of 20dB coupler making total signal attenuation 30dB on the 2 cal lines (Instead of 20dB)
- Resistance of each wire of the cryogenic cabling: 20Ohm
- Lakeshore sensors installed are DT-470-CU, use Cal table or Chebychev polynomial fit equations to convert volt to Kelvin (already implemented in python code provided)
- Vacuum Gauge: Edwards WRG: Wide range gauge: 1atm to 10^-10Torr
- Cryo harness cable#05 (3 wires) is a spare. Not connected to anything on MC end but has 2 wires shorted together (Green and white wires with a pin): this was used to measure the DC resistance of the wire harness including the cryogenic lakeshore wires. The DC resistance causes a voltage drop of the LNAs drain voltage which needs to be compensated for (Vd set at power supply: 1.8V, Vd across LNA at 14K 1.2V) . All wires of the cryo harness are identical and have same DC resistance
- Total Weight of front end is ~90LBs
- 1in thick Shims (2pcs) will be provided to mount the front end into the antenna cone such that the Feed aperture is at 22.6in (Optimum design distance) from sub-reflector when the 2 shims are used.
- The orientation/direction of POLX and Y polarizations of the feed are labeled on external cryostat cylinder. In case this information is needed (since feed can not be seen through the vacuum window material)
- Temperature of Window Material drops by ~10degrees from ambient/room temperature (I measured 15deg C in 25deg C room) due to radiative heat transfer with the cold plate electronics (Radiative cooling). Dry /Warm air inside the radome will take care of any moisture build up and will keep the window and radome surfaces dry.

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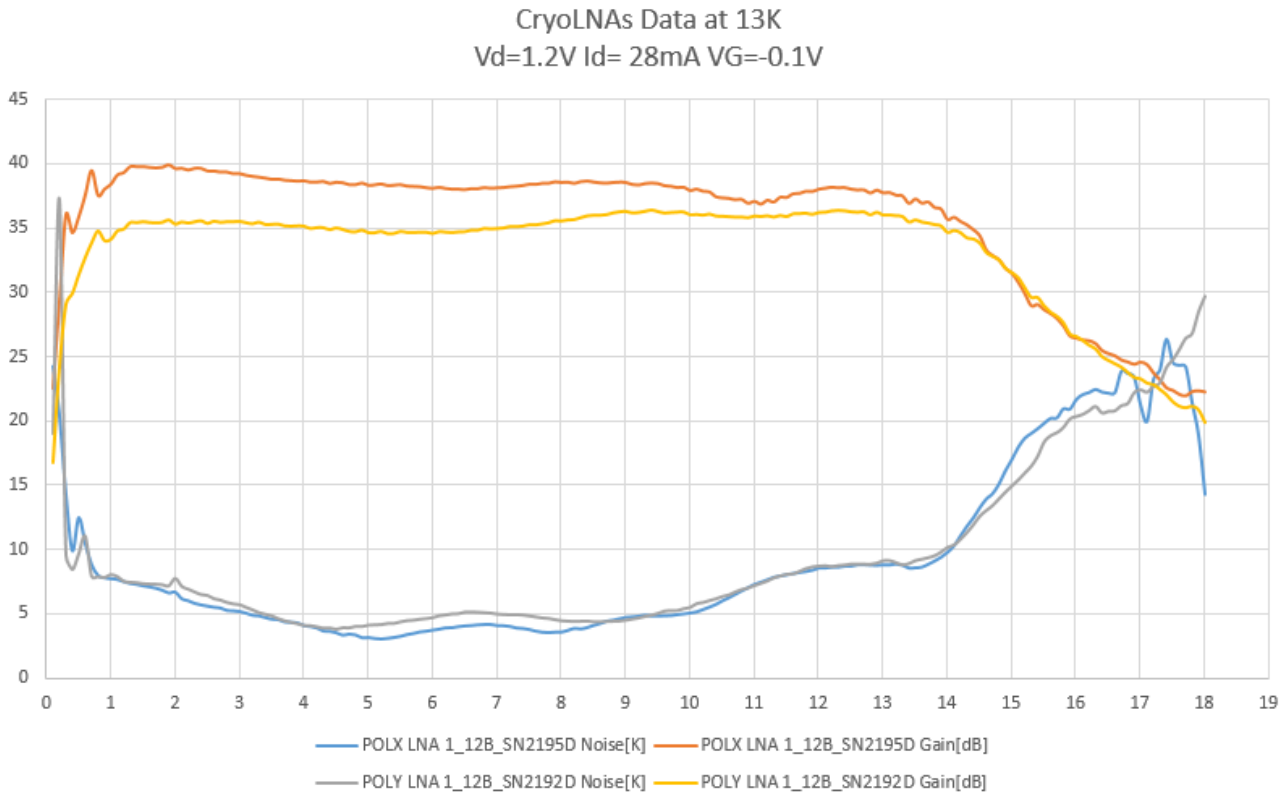
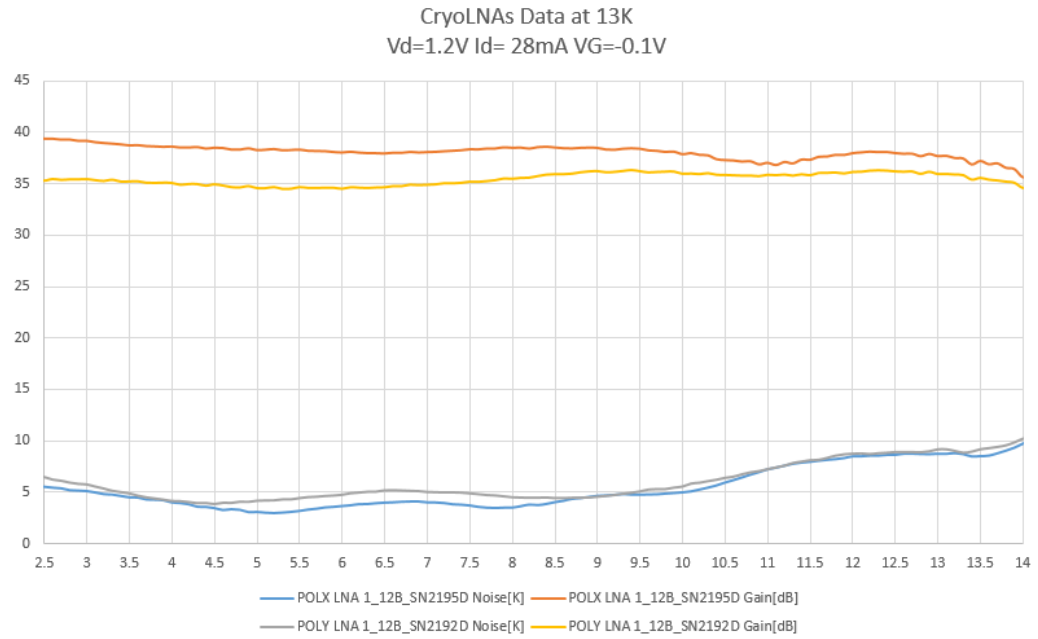
Cryogenic LNAs

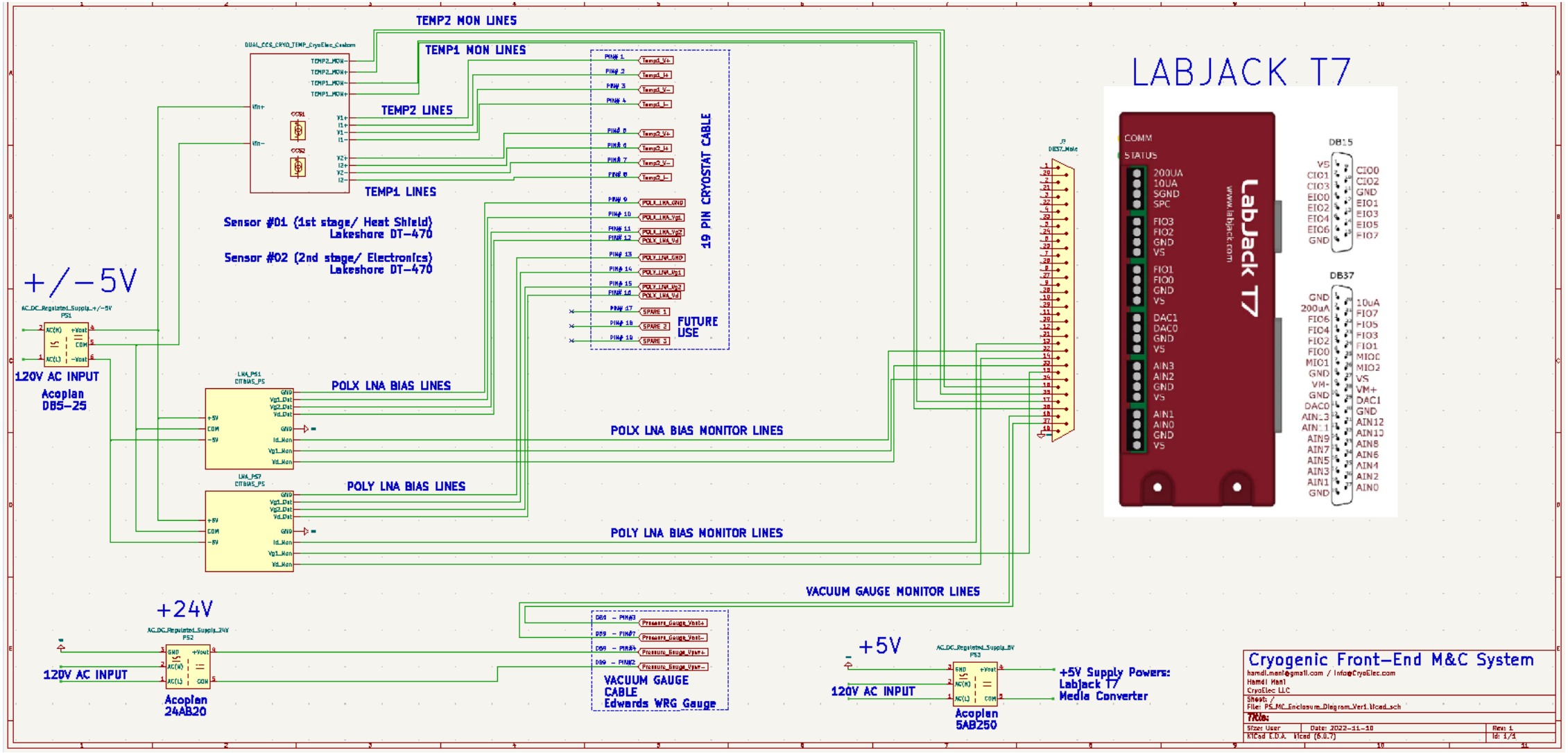




Monitor & Control System Details

Monitor & Control system Diagram (“AS BUILT”)
Ver2 11/10/2022

Labjack has static IP address: 192.168.1.200
can be changed to another address or to DHCP



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CRYOSTAT WIRING

		CRYO WIRES	VACUUM FEEDTHROUGH	Room Temp CABLES			
CRYO DEVICE	Function	Wire Color	PIN#	Cable#	MC Box	PIN#	
CRYO TEMP 1	Temp1_V+	B	1	Cable1	Aviation Connector#01	1	TEMP MON CH1
	Temp1_I+	W	2			2	
	Temp1_V-	G	3			3	
	Temp1_I-	R	4			4	
CRYO TEMP 2	Temp2_V+	B	5	Cable2	Aviation Connector#02	1	TEMP MON CH2
	Temp2_I+	W	6			2	
	Temp2_V-	G	7			3	
	Temp2_I-	R	8			4	
POLX LNA	POLX_LNA_GND	B	9	Cable3	DB9 MALE CONNECTOR X	4	LNA PS X
	POLX_LNA_VG1	W	10			1	
	POLX_LNA_VG2	G	11			2	
	POLX_LNA_VD	R	12			3	
POLY LNA	POLY_LNA_GND	B	13	Cable4	DB9 MALE CONNECTOR Y	4	LNA PS Y
	POLY_LNA_VG1	W	14			1	
	POLY_LNA_VG2	G	15			2	
	POLY_LNA_VD	R	16			3	
SPARE NC	SPARE 1	B	17	Cable5	NC		SPARE
	SPARE 2	W	18		NC		
	SPARE 3	G/R	19		NC		

B	BLACK
W	WHITE
G	GREEN
R	RED

AIN #	LABJACK I/O	DB37 PIN #	FUNCTION
1	AIN0	37	VACUUM GAUGE VOUT+
2	AIN1	18	VACUUM GAUGE VOUT-
3	AIN2	36	TEMP 1+
4	AIN3	17	TEMP 1-
5	AIN4	35	TEMP 2+
6	AIN5	16	TEMP 2-
7	AIN6	34	POLX-VG1
8	AIN7	15	POLY-VG1
9	AIN8	33	POLX-VD
10	AIN9	14	POLY-VD
11	AIN10	32	POLX-ID
12	AIN11	13	POLY-ID
	GND	19	GND

EDWARDS WIDE RANGE GAUGE				
VACUUM GAUGE	RJ45	Function	Cable#	CONNECTS TO:
	1	24V Power	Cable6	ACOPIAN 24V+
	2	Power Return		ACOPIAN 24V-
	3	Vout +		LABJACK AINO
	4	N/C		
	5	Vout -		LABJACK AIN1
	6	N/C		
	7	N/C		
	8	N/C		

M&C Enclosure

RJ45 to Fiber converter
(Mounted on Cover)

4 Mounting
Holes

All MC components turn on
When 120V AC input provided

Everything labeled to ease
Maintenance…

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Monitor points for:
- LNA Bias Voltage/current
- Pressure
- Temperatures

Temperature monitor (2CH)

Vacuum sensor monitor

POL Y LNA Power supply

POL Y LNA Power supply

Labjack T7

24V PS (Vac Gauge)

+/-5V Supply for LNAs

+5V Supply for Labjack Fiber media converter

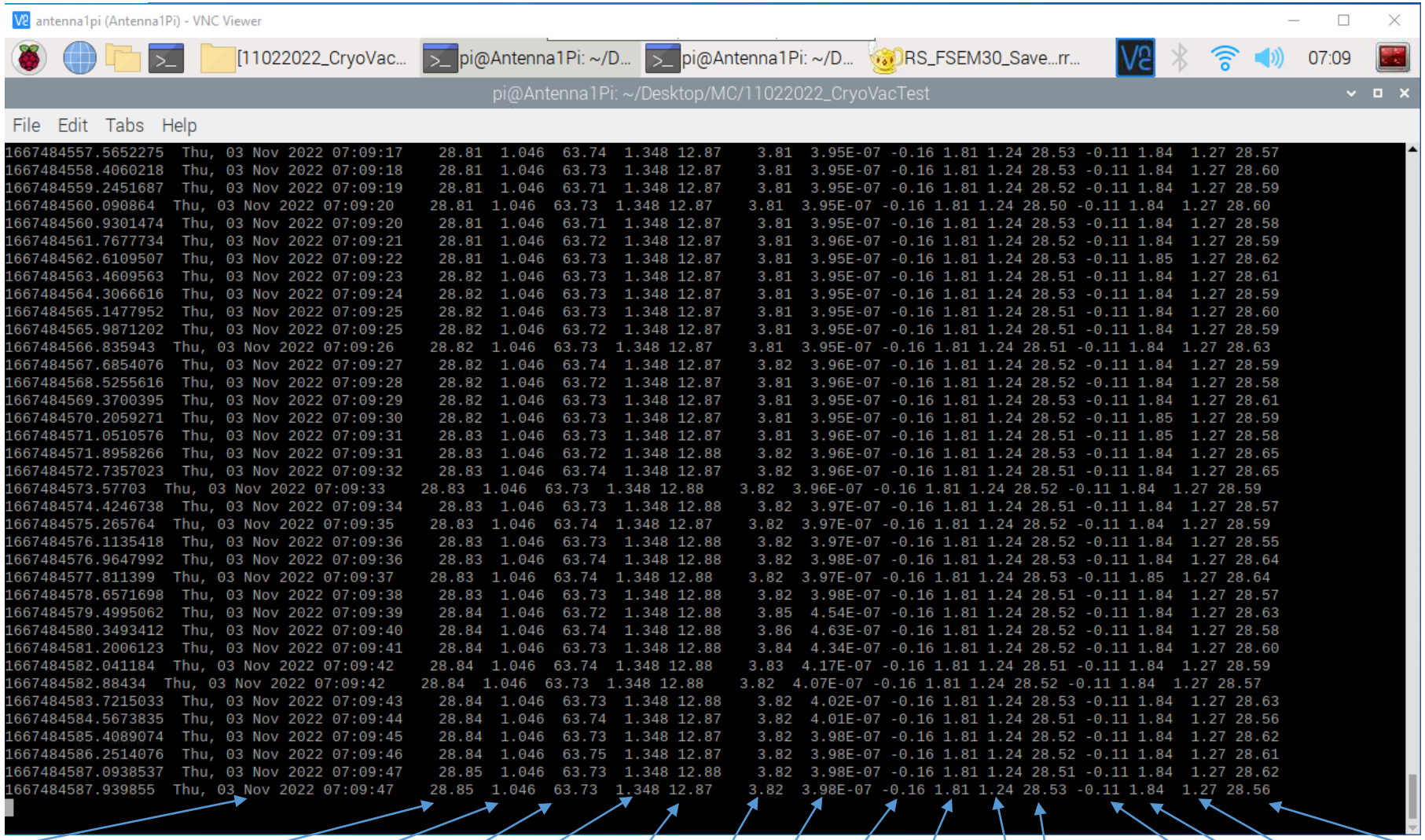
Labjack has static IP address:
192.168.1.200
can be changed to another address or to DHCP

```
##################################
#Clear All variables
def clearall():
    all = [var for var in globals() if var[0] != "_"]
    for var in all:
        del globals()[var]
clearall()
##################################
# Download and install (python setup.py install) :
# https://labjack.com/support/software/examples/ljm/python
from labjack import ljm
import time, signal , serial
import numpy as np
##################################
# Data File
filename = 'CoolDown_Start_11112022_9PM.txt'
# Time delay in seconds between successsive data fetching
delay = 0
# Number of Averaged labjack readings
avg = 50
# Resistance of bias leads
Rlead_300K  = 20
##################################
# Open first found LabJack
#lj = ljm.openS("T7", "ANY", "ANY")  # T7 device, Any connection, Any
identifier
lj=ljm.openS("T7","ETHERNET","192.168.1.200")
#Read AIN0(+) AIN1(-)
names = ["AIN0_NEGATIVE_CH", "AIN0_RANGE",
"AIN0_RESOLUTION_INDEX", "AIN0_SETTLING_US"]
aValues = [1, 0, 0, 0]
numFrames = len(names)
ljm.eWriteNames(lj, numFrames, names, aValues)

#https://labjack.com/support/datasheets/t-series/ain
#To take a differential reading on AIN2, set AIN3 as its negative channel
(AIN2-AIN3):
#Write 3 to AIN2_NEGATIVE_CH (address 41002)
#Read AIN2(+) AIN3(-)
names = ["AIN2_NEGATIVE_CH", "AIN2_RANGE",
"AIN2_RESOLUTION_INDEX", "AIN2_SETTLING_US"]
aValues = [3, 0, 0, 0]
numFrames = len(names)
ljm.eWriteNames(lj, numFrames, names, aValues)

names = ["AIN4_NEGATIVE_CH", "AIN4_RANGE",
"AIN4_RESOLUTION_INDEX", "AIN4_SETTLING_US"]
aValues = [5, 0, 0, 0]
numFrames = len(names)
ljm.eWriteNames(lj, numFrames, names, aValues)

#start new file
datafile=open(filename ,'w+')

datafile.write("%s %s %s %s %s %s %s %s %s %s %s %s %s %s %s %s %s %s
\n"%("Machine Time","Date and Time","LJ
Temperature[degC]","Vtemp1[V]","Temp1[K]","Vtemp2[V]","Temp2[K]","
Vpressure[[V]","Pressure[Torr]","POLX_VG1[V]","POLX_VD_SET[V]","P
OLX_VD_LNA[V]","POLX_ID[mA]","POLX_VG1[V]","POLX_VD1_SET[
V]","POLY_VD_LNA[V]","POLX_ID[mA]",) )
datafile.flush()
##################################
# Interrupt handler
##########################
class GracefulInterruptHandler(object):

    def __init__(self, sig=signal.SIGINT):
        self.sig = sig

    def __enter__(self):

        self.interrupted = False
        self.released = False

        self.original_handler = signal.getsignal(self.sig)

        def handler(signum, frame):
            self.release()
            self.interrupted = True

        signal.signal(self.sig, handler)

        return self

    def __exit__(self, type, value, tb):
        self.release()

    def release(self):

        if self.released:
            return False

        signal.signal(self.sig, self.original_handler)

        self.released = True
def terminate():
    print ("Closing Instrument ..." )
    #pdr.close()
##########################
#Standard Curve 10: Measurement Current = 10 µA
# Lakeshore DT-470
##########################
# 100 K to 500 K
def T_100K_500K(Z):
    ZL = 0.079767
    ZU = 0.999614
    X=((Z-ZL)-(ZU-Z))/(ZU-ZL)
    A_100K_500K =[287.756797,-194.144823,-3.837903,-1.318325,-
0.109120,-0.393265,0.146911,-0.111192,0.028877,-0.029286,0.015619]
    T = 0
    for i in range(len(A_100K_500K)):
        T = T + A_100K_500K[i]*np.cos(i*np.arccos(X))
    return T

# 24.5 K to 100.0 K
def T_24K_100K(Z):
    ZL = 0.923174
    ZU = 1.13935
    X=((Z-ZL)-(ZU-Z))/(ZU-ZL)
    A_24K_100K = [71.818025,-
53.799888,1.669931,2.314228,1.566635,0.723026,-0.149503,0.046876,-
0.388555,0.056889,-0.116823,0.058580]
    T = 0
    for i in range(len(A_24K_100K)):
        T = T + A_24K_100K[i]*np.cos(i*np.arccos(X))
    return T
```

Python M&C

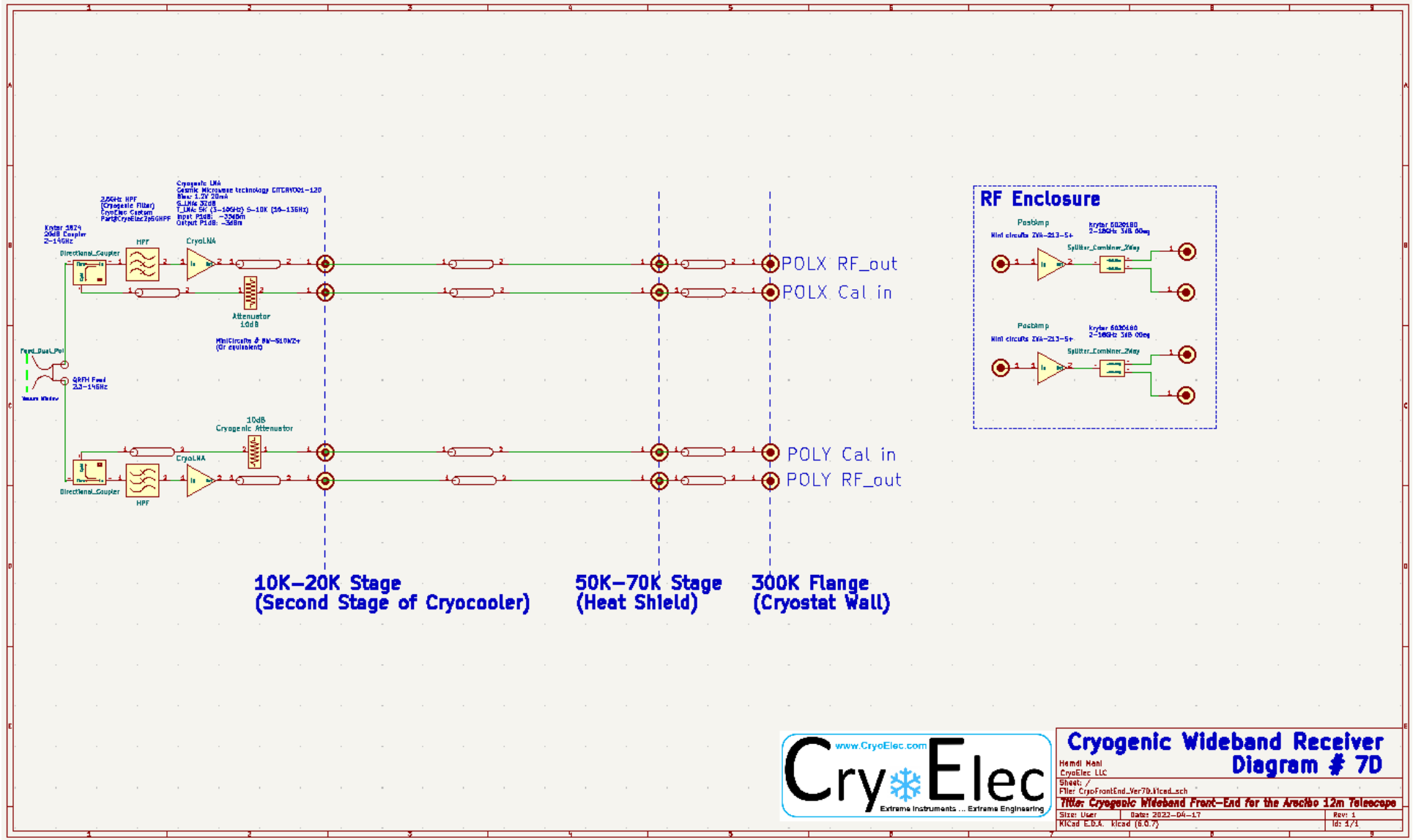
```
#12.0 K to 24.5 K
def T_12K_24K(Z):
    ZL = 1.11732
    ZU = 1.42013
    X=((Z-ZL)-(ZU-Z))/(ZU-ZL)
    A_12K_24K  = [17.304227,-7.894688,0.453442,0.002243,0.158036,-
0.193093,0.155717,-0.085185,0.078550,-0.018312,0.039255]
    T = 0
    for i in range(len(A_12K_24K)):
        T = T + A_12K_24K[i]*np.cos(i*np.arccos(X))
    return T

#2.0 K to 12.0 K
def T_2K_12K(Z):
    ZL = 1.32412
    ZU = 1.69812
    X=((Z-ZL)-(ZU-Z))/(ZU-ZL)
    A_2K_12K = [7.556358,-5.917261,0.237238,-0.334636,-0.058642,-
0.019929,-0.020715,-0.014814,-0.008789,-0.008554]
    T = 0
    for i in range(len(A_2K_12K)):
        T = T + A_2K_12K[i]*np.cos(i*np.arccos(X))
    return T

with GracefulInterruptHandler() as h:
    while True :
        Z1=[]
        Z1_avg =[]
        T1=[]
        Z2=[]
        Z2_avg =[]
        T2=[]
        v =[]
        v_avg =[]
        polx_vg1=[]
        polx_vg1_avg=[]
        polx_vd=[]
        polx_vd_avg=[]
        polx_id=[]
        polx_id_avg=[]
        poly_vg1=[]
        poly_vg1_avg=[]
        poly_vd=[]
        poly_vd_avg=[]
        poly_id=[]
        poly_id_avg=[]
        temp =[]
        temp_avg = []
        for i in range(avg):
            # Setup and call eReadName to read from AIN0 on the LabJack.
            v.append(ljm.eReadName(lj, "AIN0"))
            Z1.append(ljm.eReadName(lj, "AIN2"))
            Z2.append(ljm.eReadName(lj,"AIN4"))
            polx_vg1.append(ljm.eReadName(lj, "AIN6"))
            polx_vd.append(ljm.eReadName(lj, "AIN8"))
            polx_id.append(ljm.eReadName(lj, "AIN10")*100) #1mA / 0.01V
            poly_vg1.append(ljm.eReadName(lj, "AIN7"))
            poly_vd.append(ljm.eReadName(lj, "AIN9"))
            poly_id.append(ljm.eReadName(lj, "AIN11")*100)
            #  Read Internal temperature sensor of the Labjack T7
            #The T7 has an LM94021 temperature sensor (GS=10)
            #connected to internal analog input channel 14 (AIN14).
            #The sensor is physically located on the bottom of the PCB
            #between the AIN0/1 and AIN2/3 screw-terminals.
            temp.append(ljm.eReadName(lj, "AIN14"))
        Z1_avg=np.average(Z1)
        Z2_avg=np.average(Z2)
        v_avg=np.average(v)
        polx_vg1_avg=np.average(polx_vg1)
        polx_vd_avg=np.average(polx_vd)
        polx_id_avg=np.average(polx_id)
        polx_vd_lna=polx_vd_avg -(Rlead_300K  * polx_id_avg/1000)
        poly_vg1_avg=np.average(poly_vg1)
        poly_vd_avg=np.average(poly_vd)
        poly_id_avg=np.average(poly_id)
        poly_vd_lna=poly_vd_avg -(Rlead_300K  * poly_id_avg/1000)
        temp_avg=-0.0892* (np.average(temp) *1000) +188.61
        # Convert Voltages to temperatures
###############
        if  0.22463 < Z1_avg <=  0.97550:
            T1 = T_100K_500K(Z1_avg)
        if  0.97550  < Z1_avg <=  1.13598:
            T1 = T_24K_100K(Z1_avg)
        if  1.13598  < Z1_avg <= 1.36809 :
            T1 = T_12K_24K(Z1_avg)
        if  1.36809  < Z1_avg <=  1.68786:
            T1 = T_2K_12K(Z1_avg)
############
        if  0.22463 < Z2_avg <=  0.97550:
            T2 = T_100K_500K(Z2_avg)
        if  0.97550  < Z2_avg <=  1.13598:
            T2 = T_24K_100K(Z2_avg)
        if  1.13598  < Z2_avg <= 1.36809 :
            T2 = T_12K_24K(Z2_avg)
        if  1.36809  < Z2_avg <=  1.68786:
            T2 = T_2K_12K(Z2_avg)
############
        # Edwards WRG vacuum gauge
        P_Torr=10**(1.5*v_avg-12.125)
############
        #Print telemetry data into console and save into text file
        print ("%s  %s   %.2f  %.3f  %.2f  %.3f %.2f    %.2f  %0.2E %.2f %.2f
%.2f %.2f %.2f %.2f  %.2f %.2f"%(time.time(),time.strftime("%a, %d %b
%Y %H:%M:%S
"),temp_avg,Z1_avg,T1,Z2_avg,T2,v_avg,P_Torr,polx_vg1_avg,polx_vd_avg
,polx_vd_lna,polx_id_avg,poly_vg1_avg,poly_vd_avg,poly_vd_lna,poly_id_a
vg))
        datafile.write("%s  %s   %.2f  %.3f  %.2f  %.3f %.2f    %.2f  %0.2E
%.2f %.2f %.2f %.2f  %.2f  %.2f %.2f
\n"%(time.time(),time.strftime("%a, %d %b %Y %H:%M:%S
"),temp_avg,Z1_avg,T1,Z2_avg,T2,v_avg,P_Torr,polx_vg1_avg,polx_vd_avg
,polx_vd_lna,polx_id_avg,poly_vg1_avg,poly_vd_avg,poly_vd_lna,poly_id_a
vg) )
        datafile.flush()
        #time.sleep(delay)
        if h.interrupted:
            print( " Interrupted ... Exiting gracefully")
            terminate()
            break # Break the loop
if h.interrupted == False:
    terminate()
```

M&C Sofwatre: Python Program Output



RF System Block Diagram

Cryogenic Front End Diagram ("AS BUILT")
Ver 7D 11/07/2022



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RF Enclosure Details

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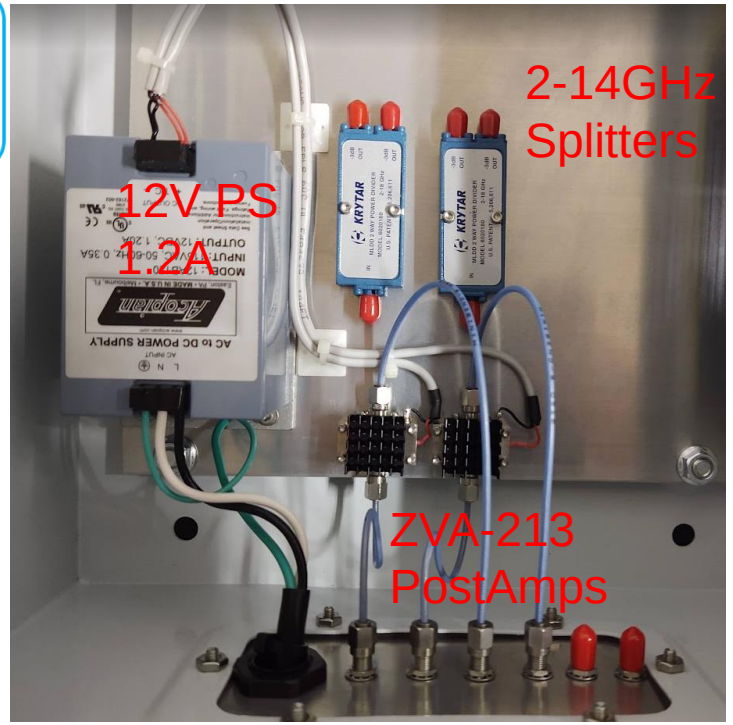
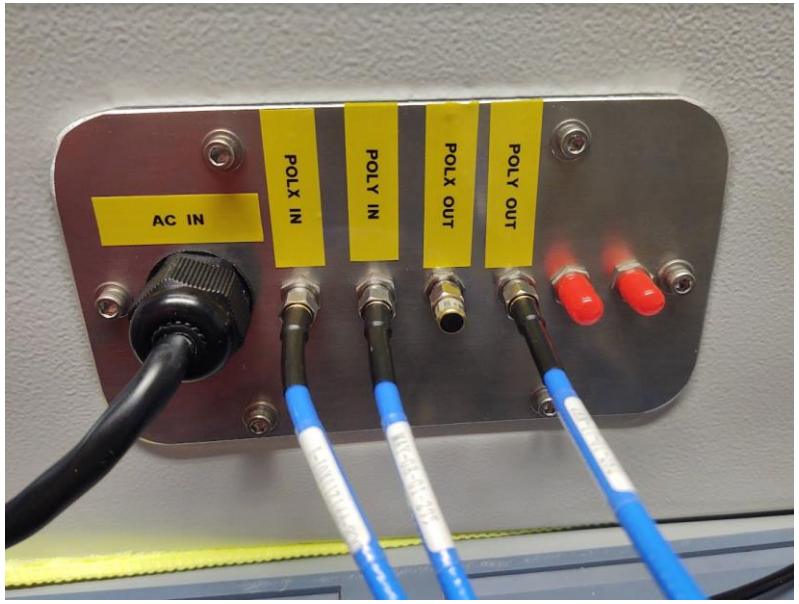
Enclosure Size:
~16.5x13x8.5in
(Same enclosure size as M&C system)



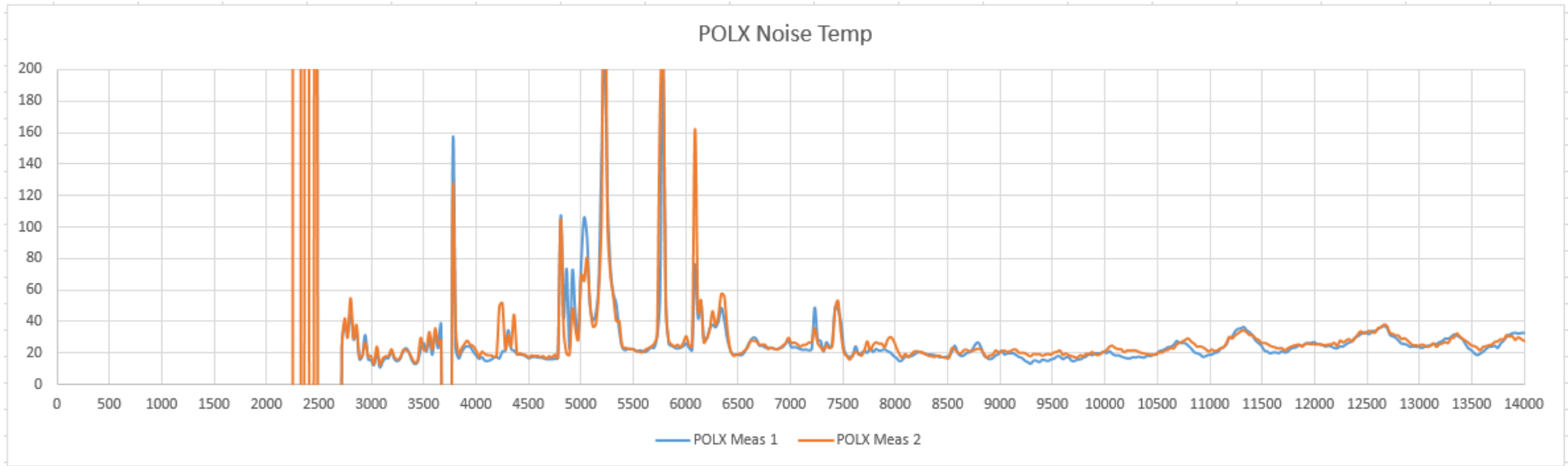
2 FANS
With 2 Metal
Mesh shields
On inside
And outside
(Can be
Turned off
Or disconnected
If not needed)

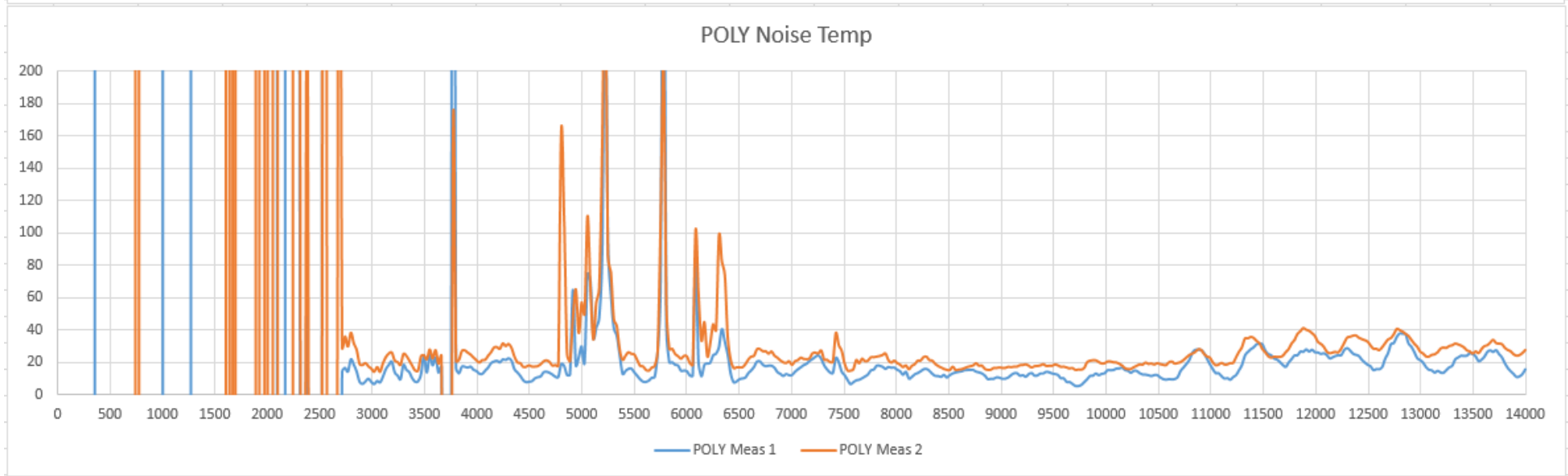


Splitters mounted
But not connected

Maximum Amp Temp: ~55C FANS OFF
~41C FANS ON
Maximum operating amp temp: +85C

Summary of Receiver Noise Temperature Data (measured at CryoElec Arizona)


POLX Noise Temp
200
180
160
140
120
100
80
60
40
20
0
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000 7500 8000 8500 9000 9500 10000 10500 11000 11500 12000 12500 13000 13500 14000
POLX Meas 1
POLX Meas 2


POLY Noise Temp
200
180
160
140
120
100
80
60
40
20
0
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000 7500 8000 8500 9000 9500 10000 10500 11000 11500 12000 12500 13000 13500 14000
POLY Meas 1
POLY Meas 2

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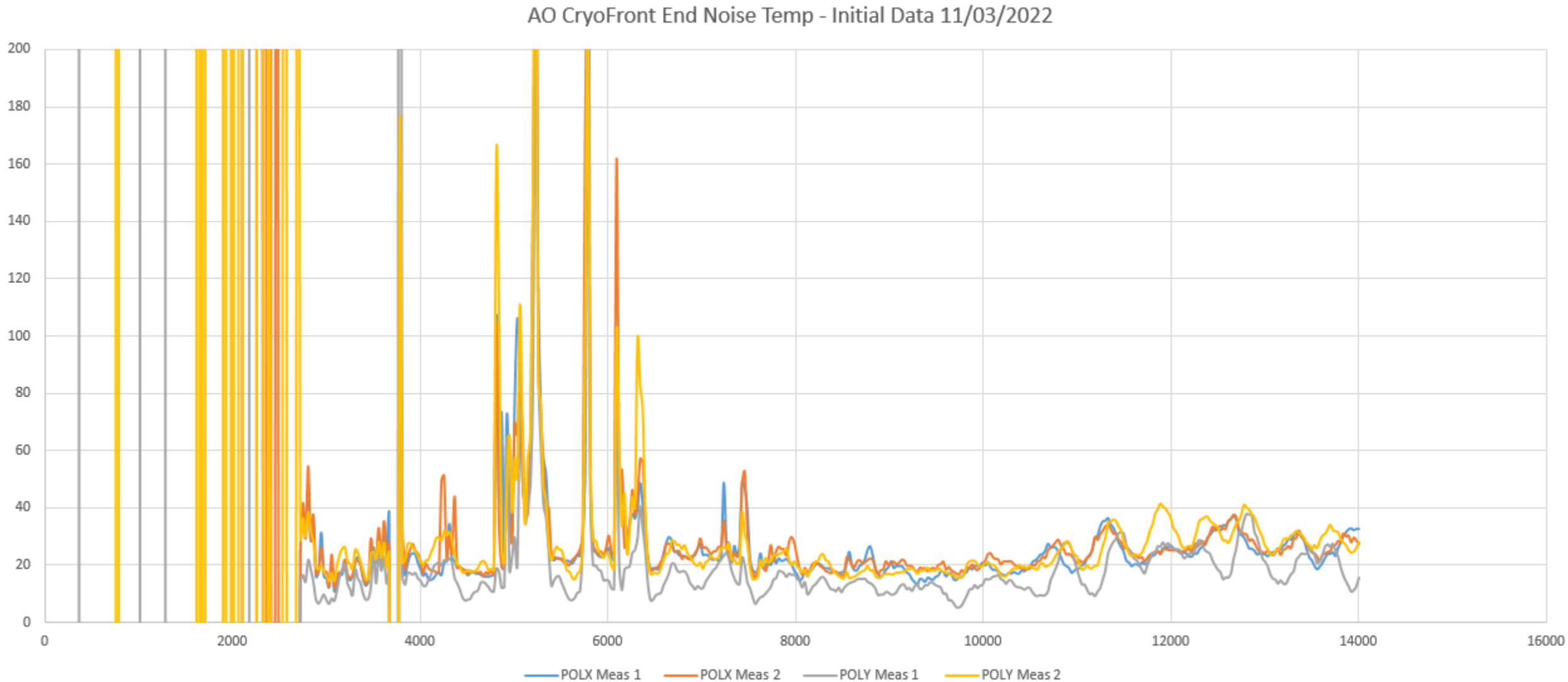

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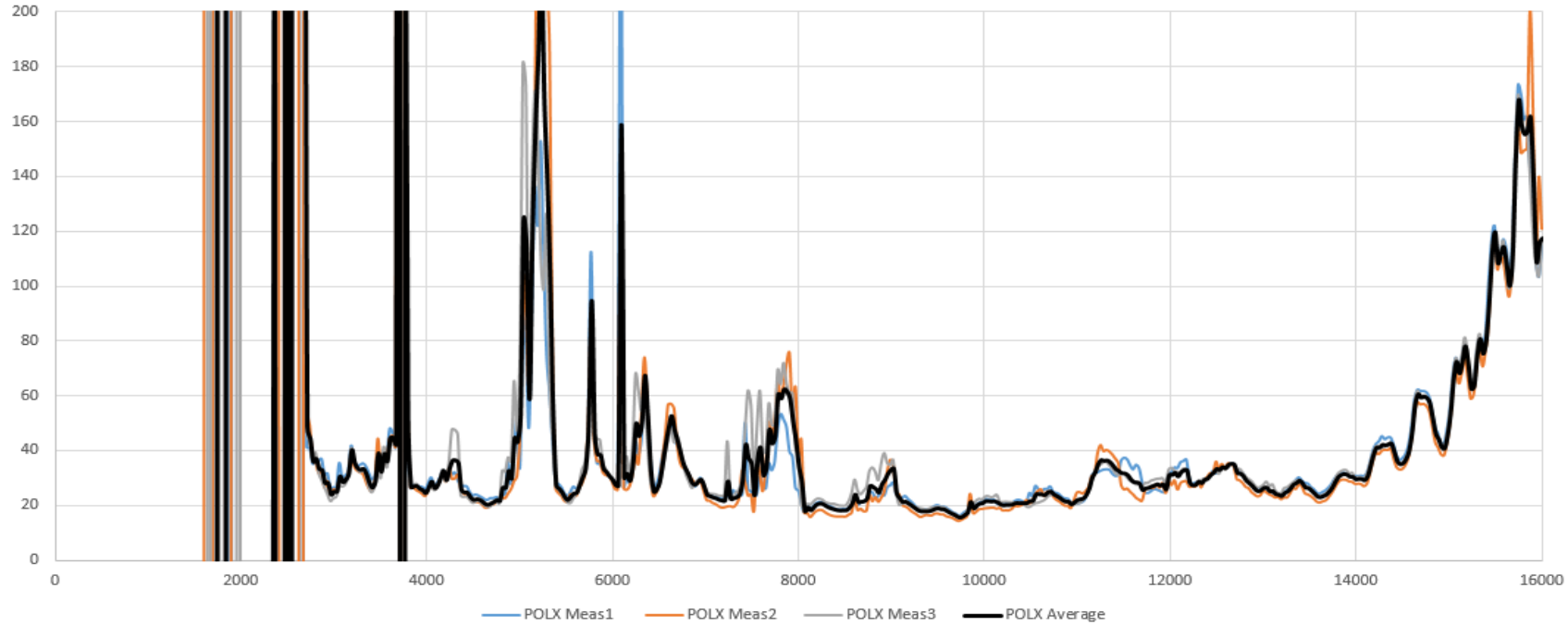
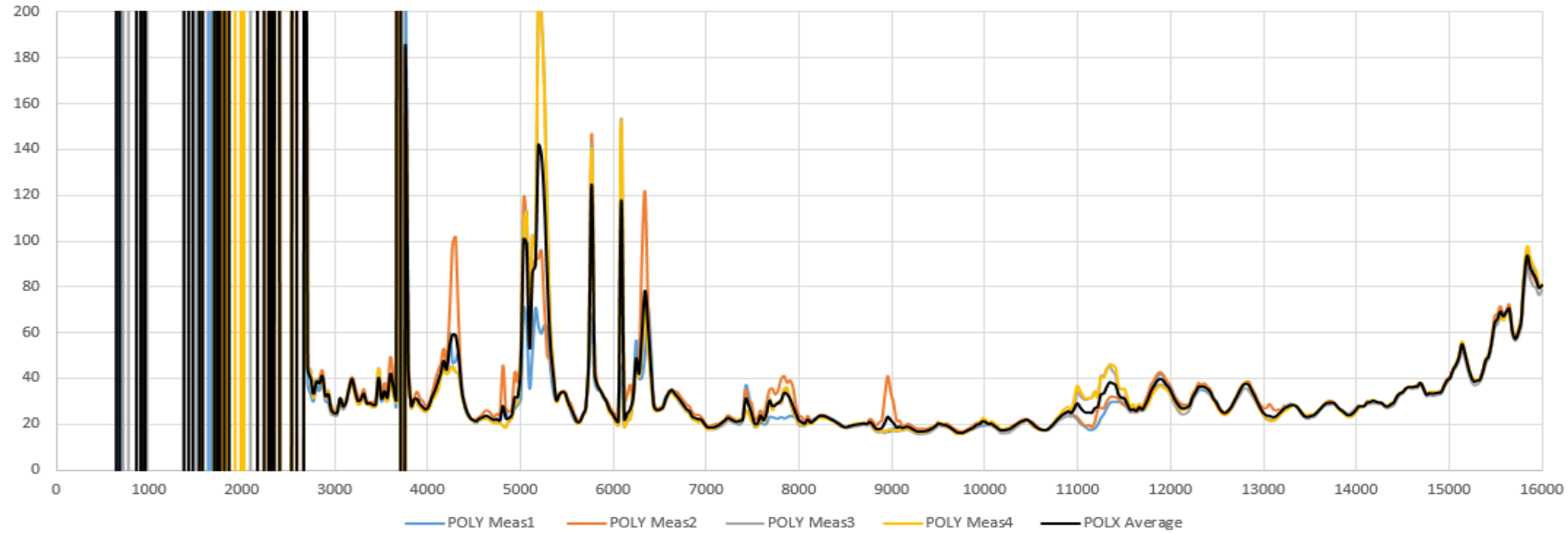
POLX Y-Factor Measurement using 300K ABS / 10K SKY



POLY Y-Factor Measurement using 300K ABS / 10K SKY



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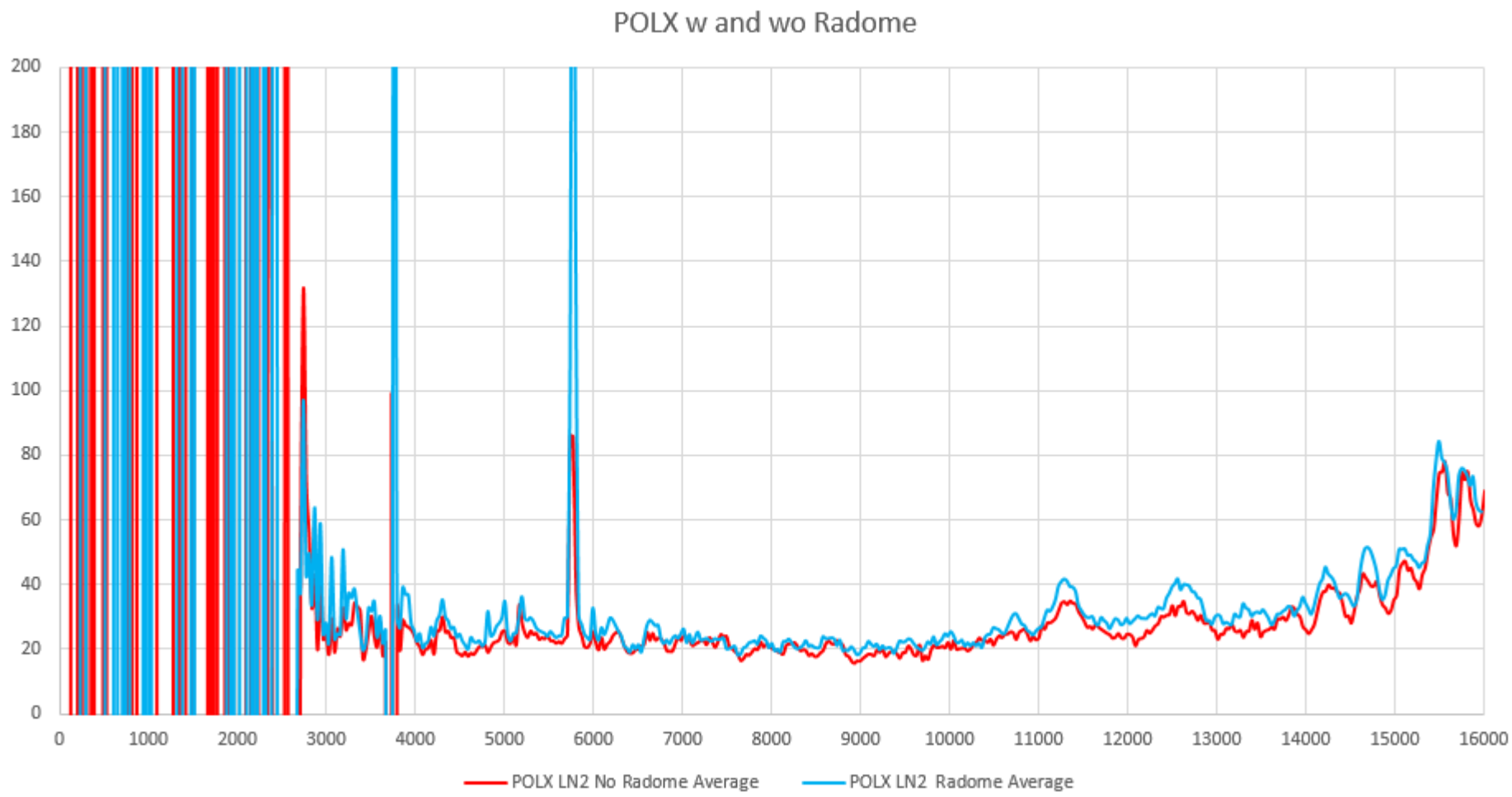

FLAT Radome Installed

No Radome

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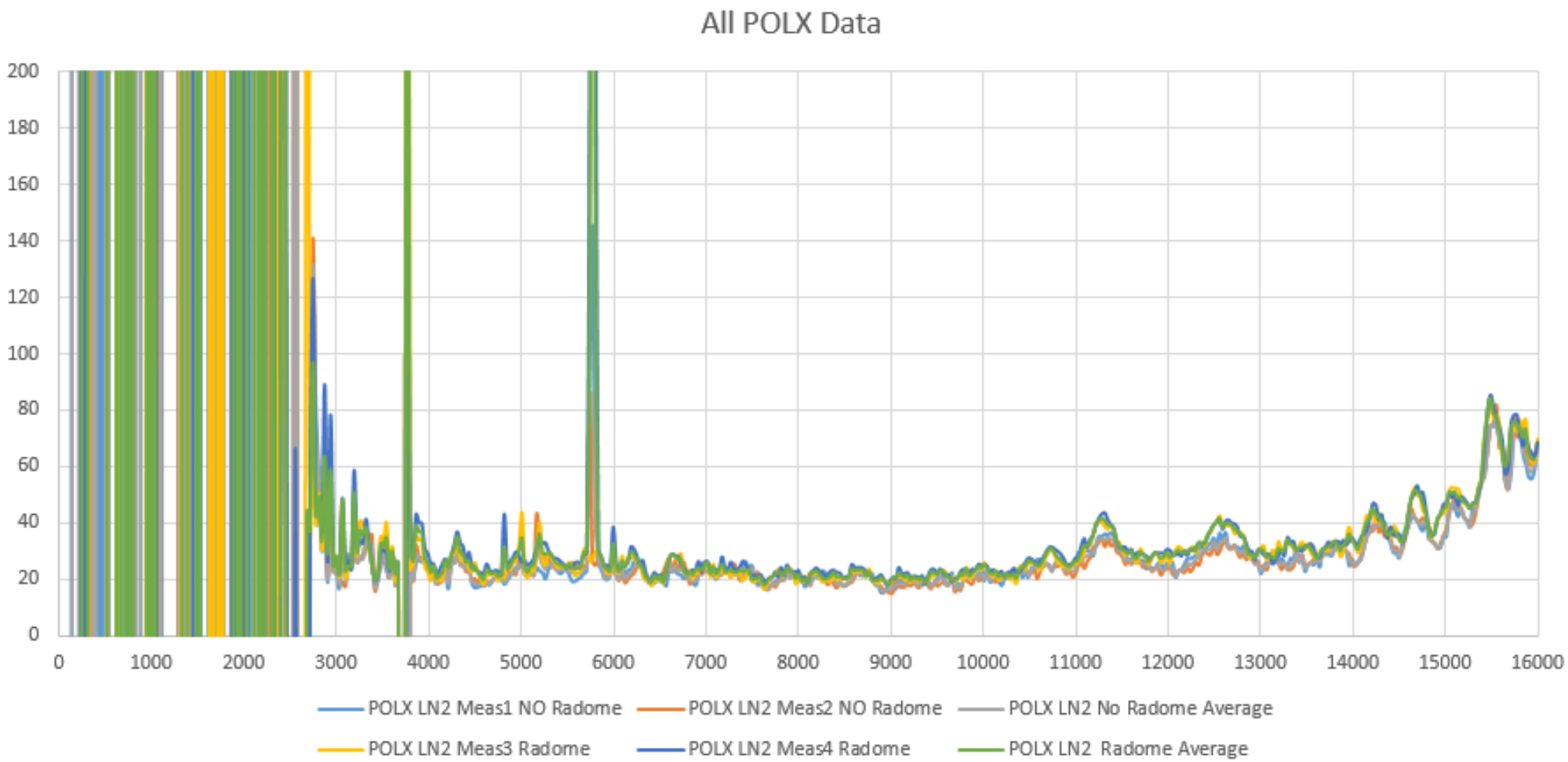
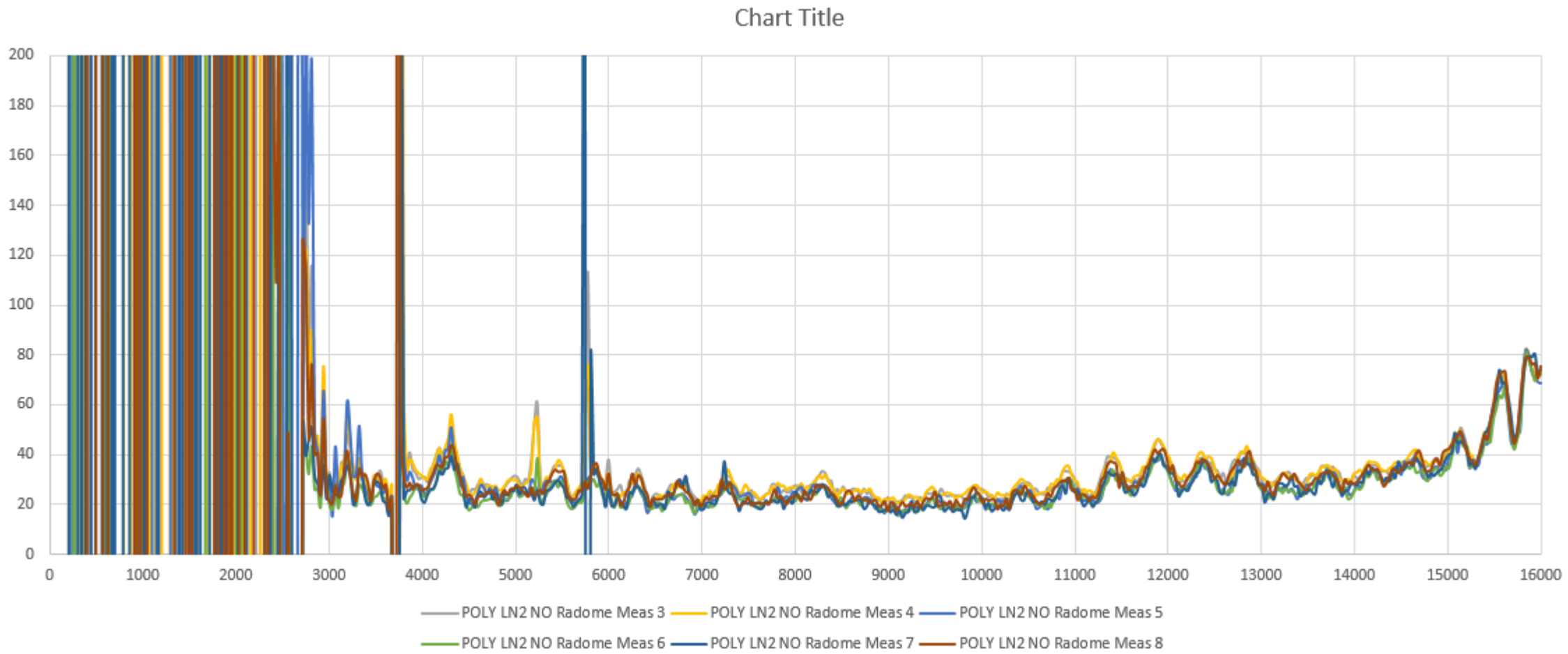
11/15/2022 Data POL X



11/15/2022 Data

POLY Data with and without radome



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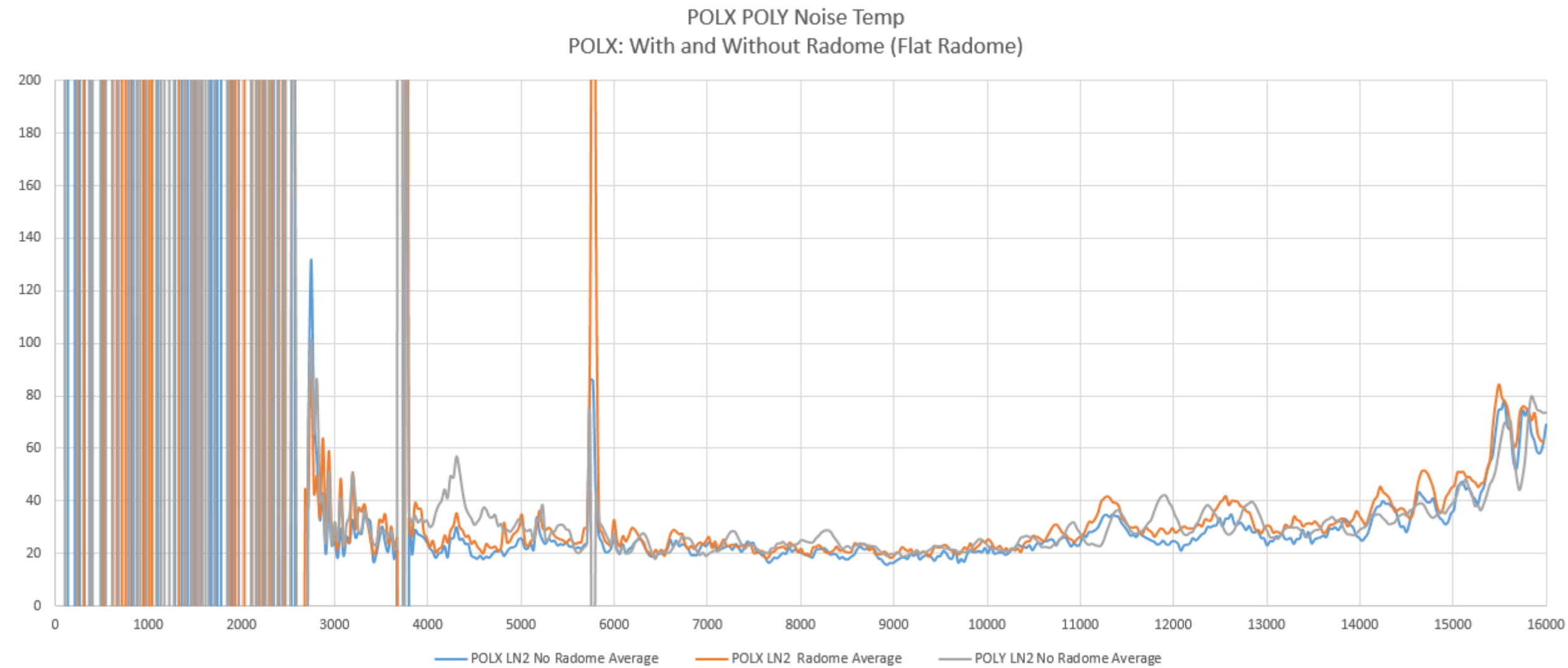
11/15/2022 Data



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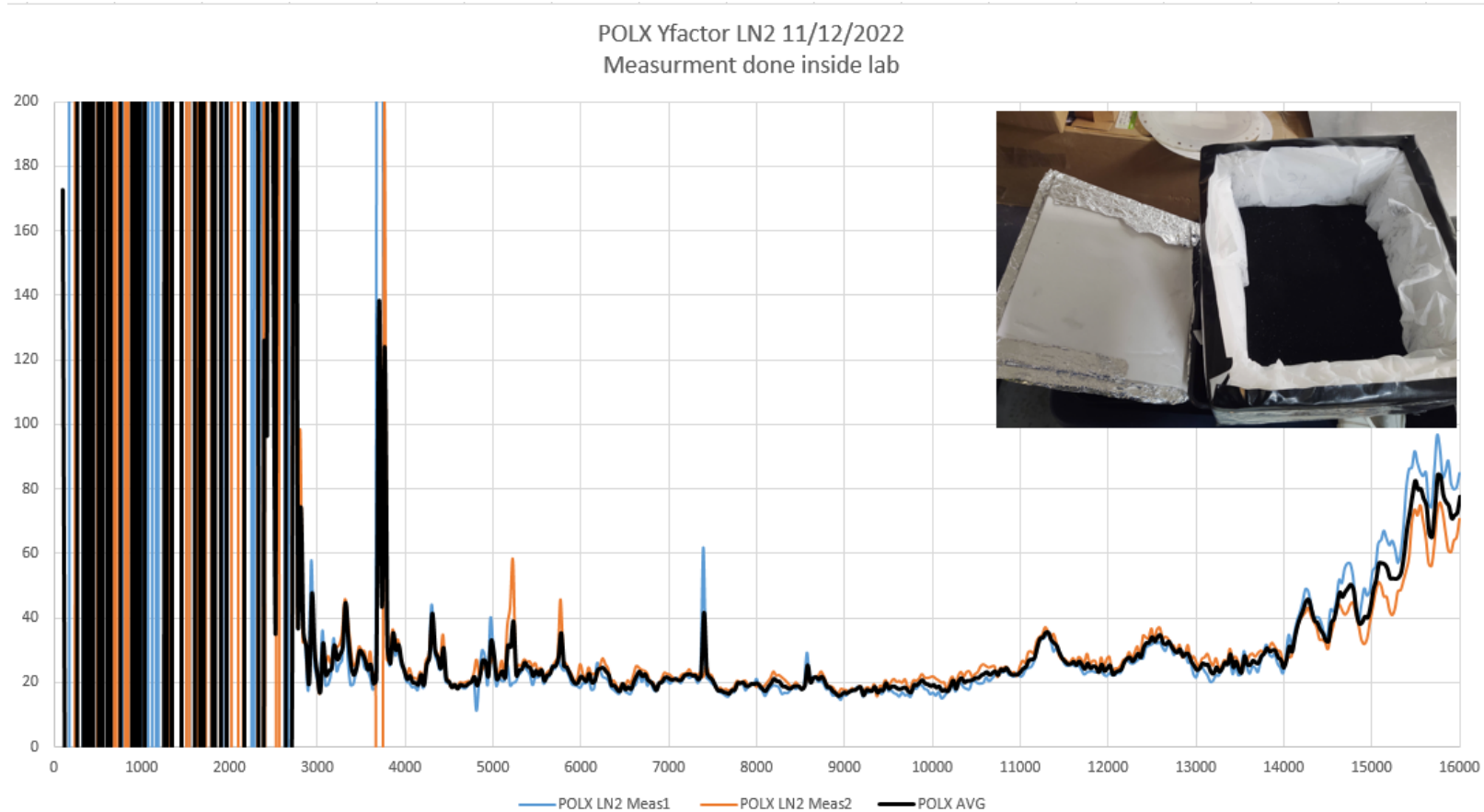

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