North Texas NTMS Microwave Society

Texas Weather box

June 4, 2022

KM5PO – KI5EMN

The learning curve

- Need to understand all factors of path loss at higher microwave frequencies to improve success.
  - We had a CW/599 success at 17 km then could not repeat one week later and had issues falling back to 6.5 km
- More testing needs to occur while taking weather measurement data in real time at operating points
  - Weatherbox simplifies accurate data capture
- Need comprehensive measured atmospheric data
  - “Along the path” measurements
  - Integration of additional probes
  - 3rd party weather reporting
- Refined characterization of system parameters
  - Dish & Feed alignment
  - Phase noise effects
    - External reference

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Red Kites (thermal) day

Terrain	length	Percent
Urban	10.8 km	63.5%
Rural	3.8 km	22.4%
Water	2.4 km	14.1%

122.350 GHz/*sys parms					Estimated/Predicted values									
Date	dx km	Temp C	RH	hPa	Free S PL	Atmos GL	Tot PL	TX EIRP	RX sig	RX noise T/K	RX Noise Power	RX S/N	Actual S/N	Note
3/12/2022	17	13	15	1001.9	158.8	6.7	165.5	32	-115.5	4306.2	-135.3	19.8	15	0-5 knot wind
3/19/2022	17	24	15	978.5	158.8	7.5	166	32	-116.3	4306.2	-135.3	19	5	15 knot winds
							0.8		-0.8			-0.8		
TX:-3/TG:35/RNF:12/RG:18/RBW:500														

Terrain	length	Percent
Urban	4.3 km	66.2%
Rural	0 km	0.0%
Water	2.2 km	33.8%

- Did the observed thermal activity come from urban surface heating on the warmer day?

The Standard

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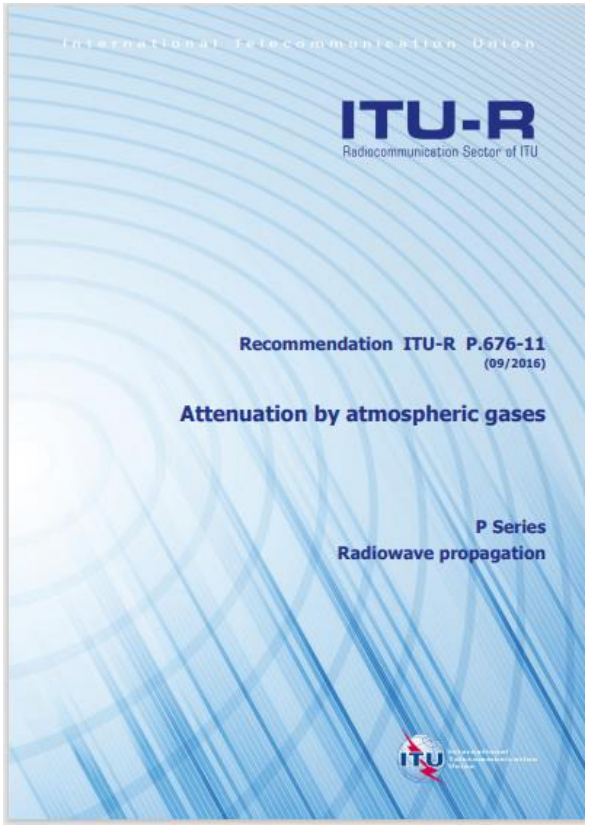

This is our standard for calculating attenuation by atmospheric gases for frequencies 1-1000 GHz.

Contains the formulas and two tables that list frequency points and the related oxygen attenuation and water-vapor attenuation.

The Weatherbox code implements these tables and formulas. Thank you Barry G8AGN.

The Standard

The line-shape factor is given by:

$$F_i = \frac{f}{f_i}\left[\frac{\Delta f - \delta(f_i - f)}{(f_i - f)^2 + \Delta f^2} + \frac{\Delta f - \delta(f_i + f)}{(f_i + f)^2 + \Delta f^2}\right] \quad (5)$$

where f_i is the oxygen or water vapour line frequency and Δf is the width of the line:

$$\begin{aligned} \Delta f &= a_3 \times 10^{-4}\,(p\,\theta^{(0.8\,-\,a_4)} + 1.1\,e\,\theta) && \text{for oxygen} \\ &= b_3 \times 10^{-4}\,(p\,\theta^{b_4} + b_5\,e\,\theta^{b_6}) && \text{for water vapour} \end{aligned} \quad (6a)$$

The line width Δf is modified to account for Zeeman splitting of oxygen lines and Doppler broadening of water vapour lines:

$$\begin{aligned} \Delta f &= \sqrt{\Delta f^2 + 2.25\times 10^{-6}} && \text{for oxygen} \\ &= 0.535\Delta f + \sqrt{0.217\Delta f^2 + \frac{2.1316\times 10^{-12} f_i^2}{\theta}} && \text{for water vapour} \end{aligned} \quad (6b)$$

δ is a correction factor that arises due to interference effects in oxygen lines:

$$\begin{aligned} \delta &= (a_5 + a_6\theta)\times 10^{-4}(p+e)\theta^{0.8} && \text{for oxygen} \\ &= 0 && \text{for water vapour} \end{aligned} \quad (7)$$

```
// water vapour
sf = 0.0L;
 for (int i = 0; i < 35; i++) {
  s = 0.1L * b1[i] * e * pow(theta, 3.5L) * exp(b2[i] * (1.0L - theta));
  df = 0.0001L * b3[i] * (p * pow(theta, b4[i]) + b5[i] * e * pow(theta, b6[i]));
  df1 = 0.535L * df;
  df = df1 + sqrt(0.217L * df * df + (2.1316e-12 * fw[i] * fw[i]) / theta);
  t1 = df / ((fw[i] - f) * (fw[i] - f) + df * df);
  t2 = df / ((fw[i] + f) * (fw[i] + f) + df * df);
  bf = f * (t1 + t2) / fw[i];
  sf = sf + s * bf;
 }
 gammaw = 0.182L * f * sf * path_length;

 // oxygen
 sf = 0.0L;
 for (int i = 0; i < 44; i++) {
  s = 0.0000001L * a1[i] * p * theta * theta * theta * exp(a2[i] * (1.0L - theta));
  df = 0.0001L * a3[i] * (p * pow(theta, (0.8L - a4[i])) + 1.1L * e * theta);
  df = sqrt(df * df + 0.00000225L);
  delta = 0.0001L * (a5[i] + a6[i] * theta) * (p + e) * pow(theta, 0.8L);
  t1 = (df - delta * (fo[i] - f)) / ((fo[i] - f) * (fo[i] - f) + df * df);
  t2 = (df - delta * (fo[i] + f)) / ((fo[i] + f) * (fo[i] + f) + df * df);
  bf = f * (t1 + t2) / fo[i];
  sf = sf + s * bf;
 }
```

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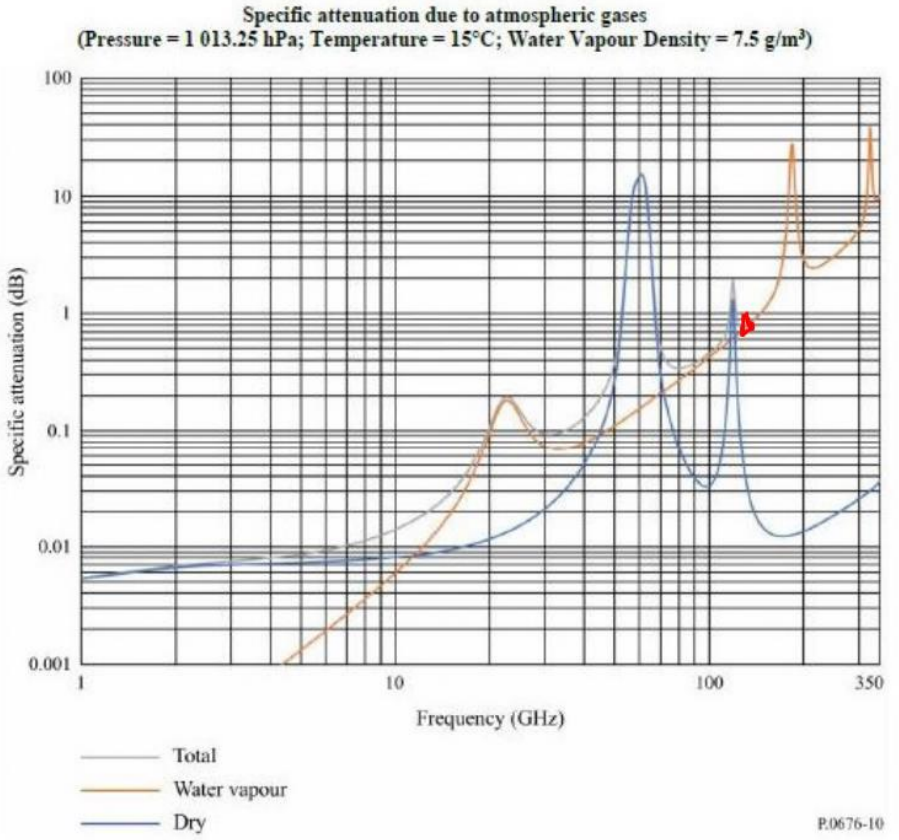
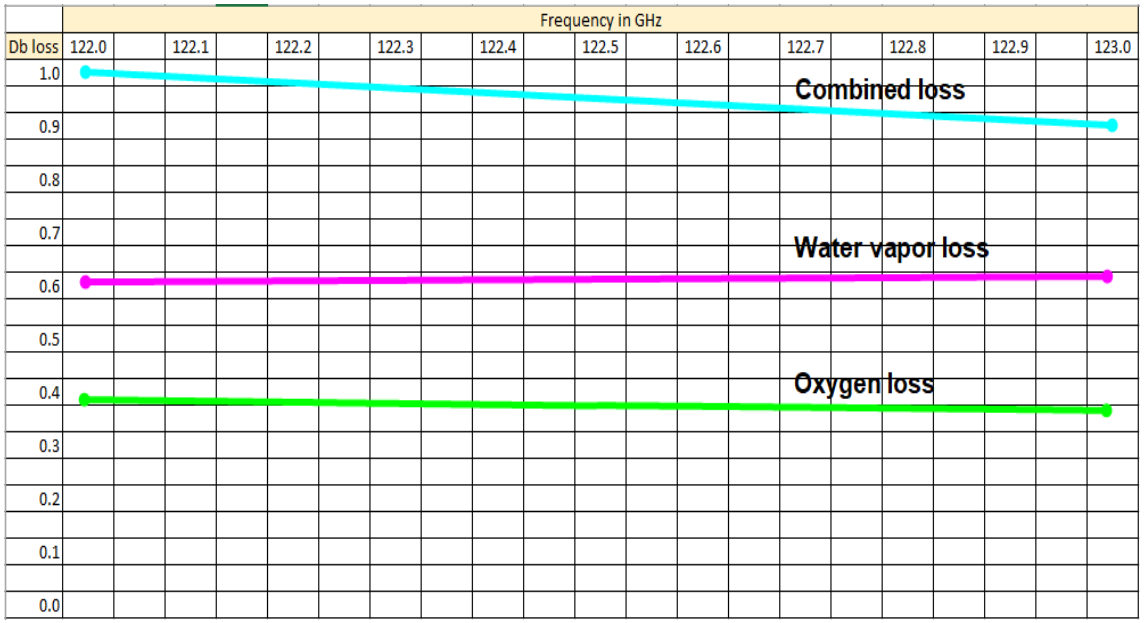
Gas losses



- 118.75 GHz nearest peak
- Dry air O2 res, Water Vapor Density = Sea Level

Gas losses over the band



- dB/km losses calculated at 1000 hPa, 15C, 60% RH
- Operation at 123 GHz results in approx. .1 dB/km improvement (1.7 dB @ 17 km etc)

Effects of variables

Gas losses result from the effects of temperature, pressure and humidity .

Temp C	Gas Loss/km
15	0.9
25	1.3
35	2.3

- Vary temperature while maintaining 1000 hPa and 60% RH
- Tests done in cooler temps yet high RH will benefit us >1 dB

hPa	Gas Loss/km
950	0.86
1000	0.90
1050	0.91

- Vary pressure while maintaining temp 15C and 60% RH
- Tests done in low pressure yet high RH will benefit us < .1 dB

RH	Gas Loss/km
20	0.4
40	0.6
60	0.9

- Vary humidity while maintaining 1000 hPa and temp 15C
- Test done in low humidity yet high pressure will benefit us ~ .5 dB

60% fixed RH = 4.76 gm/m3 at 5ºC but 12.1 gm/m3 at 20ºC

VIM-GLO-IND-Humidity-conversion-formulas-Technical-eBook-B210973EN-K.pdf (vaisala.com)

Summary

- Propagation studies at high microwave frequencies will remain a work in progress
  - Collect key data that impacts atmospheric gas losses and use a weatherbox or the online calculator (Path Loss Calculator (vk5microwave.net)
  - Share the data and your actual results
- Make tests on cool days since the atmosphere will hold less water regardless of RH reported
- Wind is not our friend
- Lower pressure yields slightly lower losses
- Operate high in the band

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Texas weatherbox!

5” square

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Same core functions

Features

- New form factor incorporating touchscreen
  - Inspired by KI5EMN
  - Nextion IDE for UI design/code
  - Nextion library required modifications (mods are documented in the Arduino sketch)
- Same peripherals
  - GPS
  - BME280 humidity/temperature sensor
  - SD-card interface
- Same core path loss calculation code with ITU implemented attenuation formulas by Barry G8AGN

Screen flow-Splash & Help Menu

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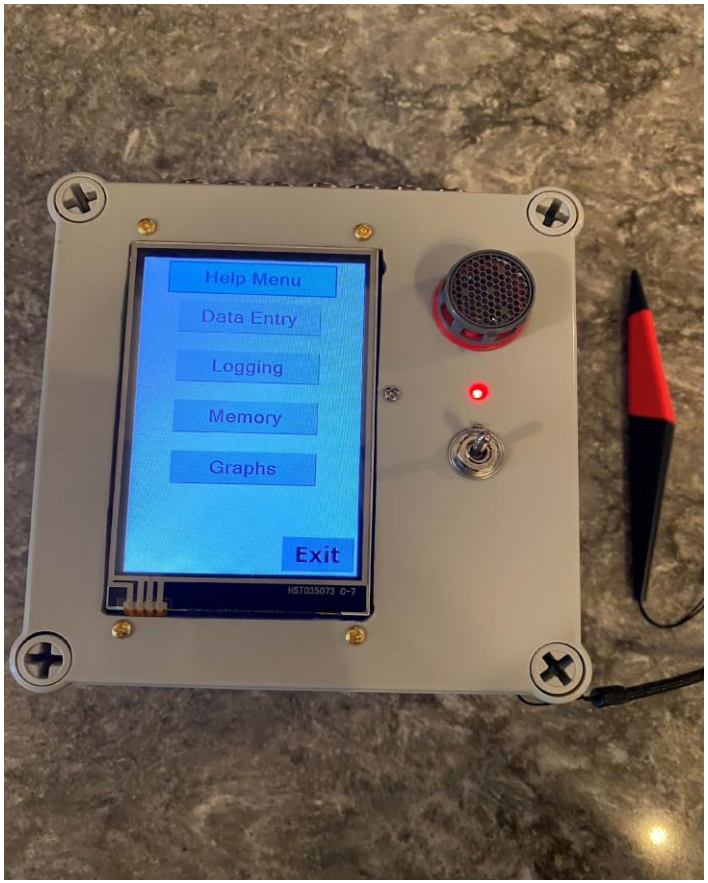

Screen flow-Data Entry

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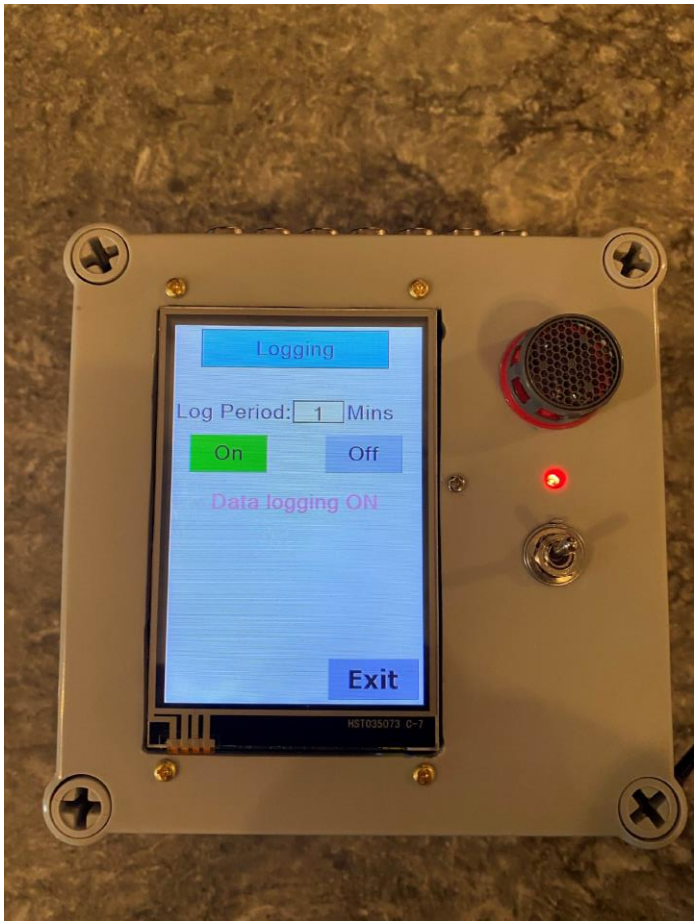
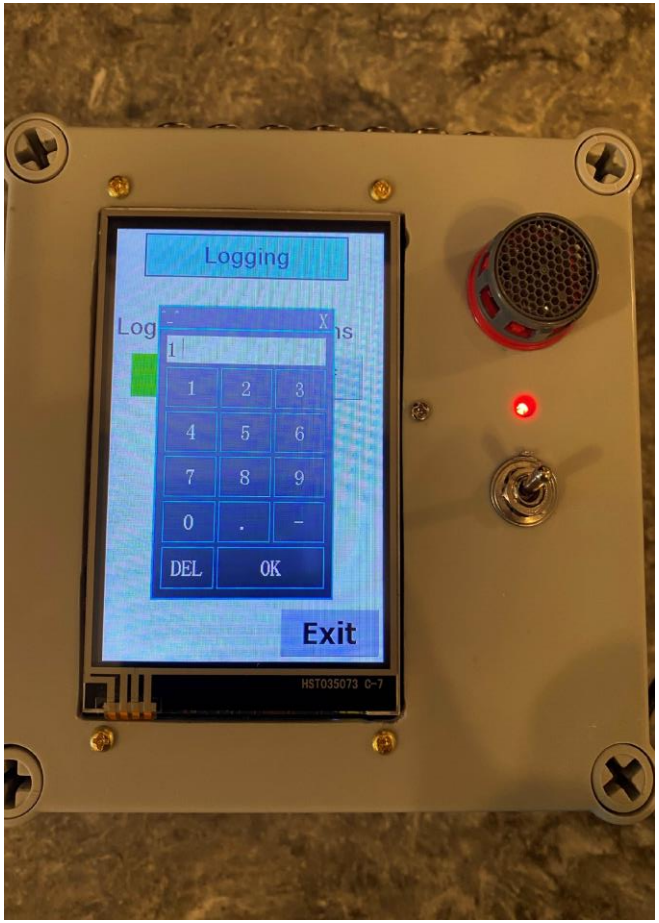
Loads the current default system parameters which can be changed here and then saved.

Exiting this menu takes you back to the Help Menu

Screen flow-Logging





Screen flow-Memory

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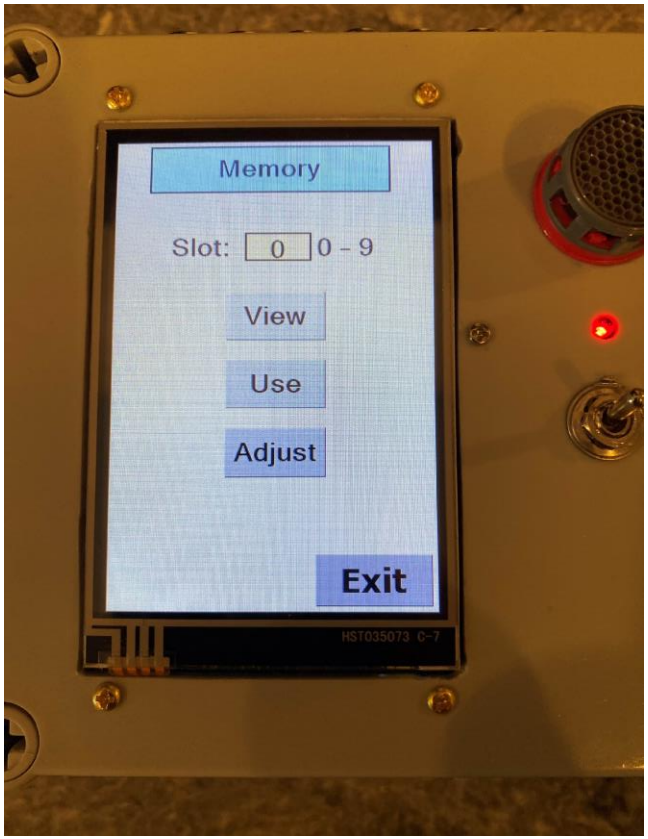
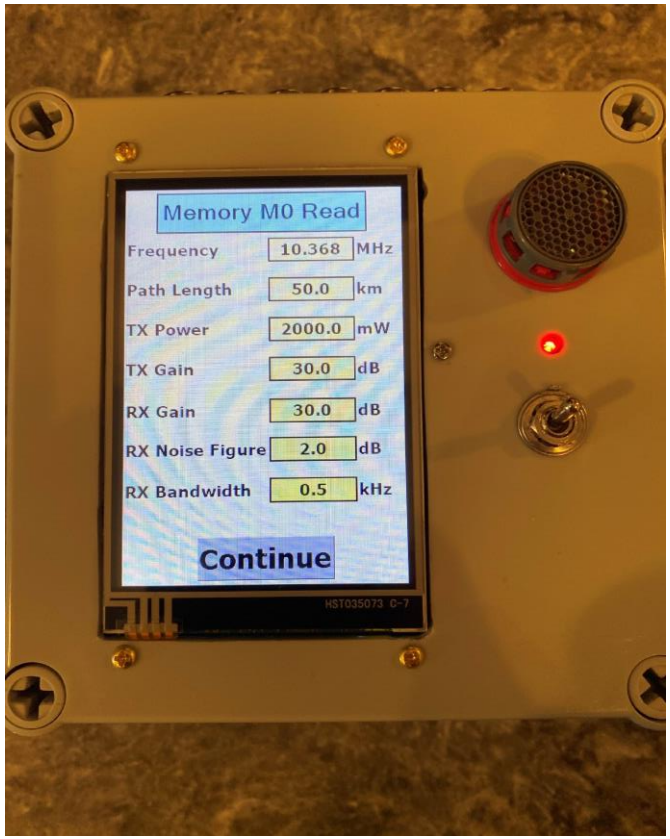
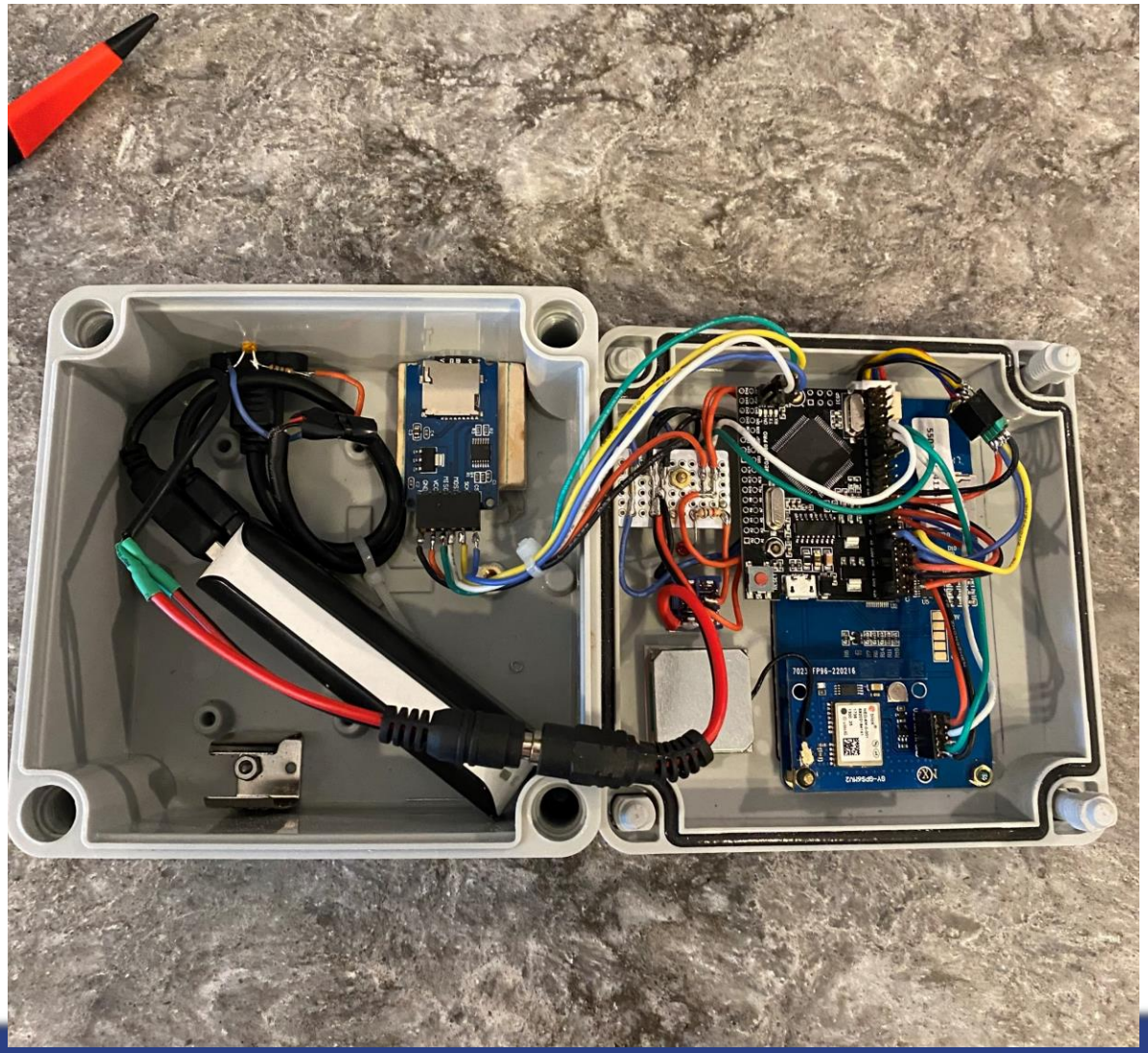
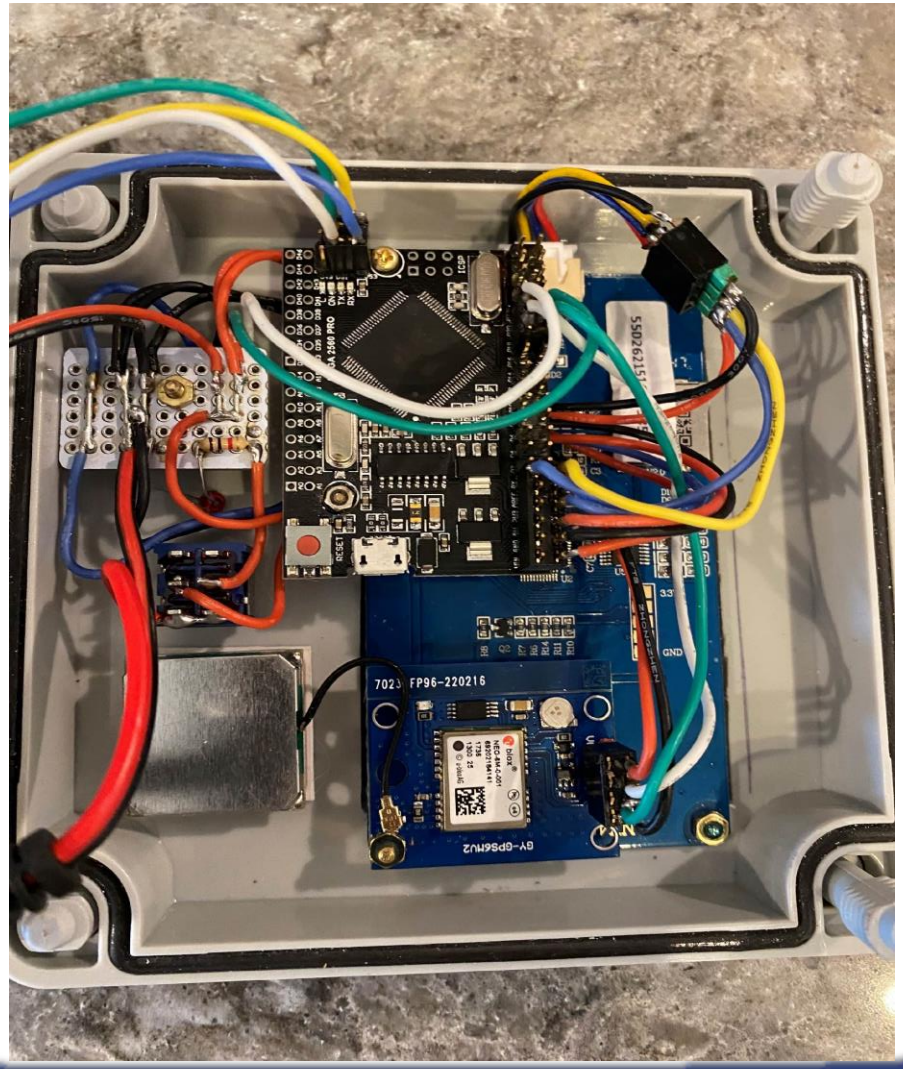




Inside



Inside



Logging

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```
EM12MU78UI 40622
122.350 17.0 0.50 40 18 12 0.5

time    p    t    RH  H20  GL  PL   C/N

13:45,997.1,23.1,75.6,15.7,28.1,186.9,3.3,182.6,EM12MU78UI
13:47,997.6,23.1,75.5,15.7,28.1,186.9,3.3,190.9,EM12MU78UJ
13:48,997.4,23.5,75.0,15.9,28.4,187.3,3.0,192.6,EM12MU78UI
13:49,997.4,23.7,73.9,15.8,28.2,187.1,3.2,189.0,EM12MU78UI
13:50,997.3,24.1,72.9,16.0,28.4,187.2,3.0,165.7,EM12MU78UH
13:51,997.2,24.5,72.0,16.1,28.5,187.3,2.9,128.7,EM12MU78UH
13:52,997.0,24.5,71.4,16.0,28.3,187.1,3.2,163.8,EM12MU78UH
13:53,997.7,24.1,71.0,15.6,27.6,186.4,3.9,155.7,EM12MU78UH
13:54,996.9,24.5,71.6,16.0,28.3,187.2,3.1,154.4,EM12MU78UH
13:55,997.4,24.5,70.0,15.7,27.7,186.5,3.7,183.0,EM12MU78UI
13:56,997.2,25.0,69.7,16.0,28.2,187.0,3.3,198.0,EM12MU78UI
13:57,996.9,25.1,68.7,15.9,27.9,186.7,3.5,177.4,EM12MU78UI
13:58,996.8,26.2,65.7,16.2,28.0,186.8,3.5,171.1,EM12MU78UI
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14:06,996.7,27.1,62.0,16.1,27.4,186.3,4.0,143.5,EM12MU78TI
14:07,997.2,27.2,61.2,16.0,27.3,186.1,4.2,152.7,EM12MU78UI
14:08,997.3,26.7,62.0,15.7,26.9,185.7,4.5,155.8,EM12MU78UI
14:09,997.4,27.8,59.8,16.1,27.3,186.1,4.1,151.5,EM12MU78UH
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14:12,997.5,28.5,57.6,16.1,27.1,185.9,4.4,154.2,EM12MU78UI
14:13,997.0,27.8,58.7,15.8,26.8,185.6,4.7,158.1,EM12MU78UI
14:14,996.6,28.1,58.2,15.9,26.9,185.7,4.6,153.5,EM12MU78UI
14:15,996.4,29.4,54.9,16.1,26.8,185.6,4.7,152.6,EM12MU78UH
```

Pin out guide

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GPS module - NEO-6 or 7 GPS	GPS pin	Mega 2560 pin
	VCC	5V
	Gnd	Gnd
	TX	19 (RX1)
	RX	18 (TX1)
Bosch BME280 weather sensor	Sensor pin	Mega 2560 pin
	VCC	3.3V
	Gnd	Gnd
	SDA	20(SDA)
	SCL	21(SCL)
SD Card Interface board	SD card pin	Mega 2560 pin
	MISO	50
	MOSI	51
	SCLK	52
	CS	53
Nextion Display	Nextion pin	Mega 2560 pin
	VCC	5V
	Gnd	Gnd
	RX1	Tx0
	TX0	Rx0

Next steps

- Graphing
- Fit remote sensor and GPS via cat5
  - Remote sensor tests good on bench with 25 feet cat5
- API for cloud-based log collection/aggregation
  - Start by uploading current logs for integration
- Develop weather probe idea
- Get outdoors and test!

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Questions?