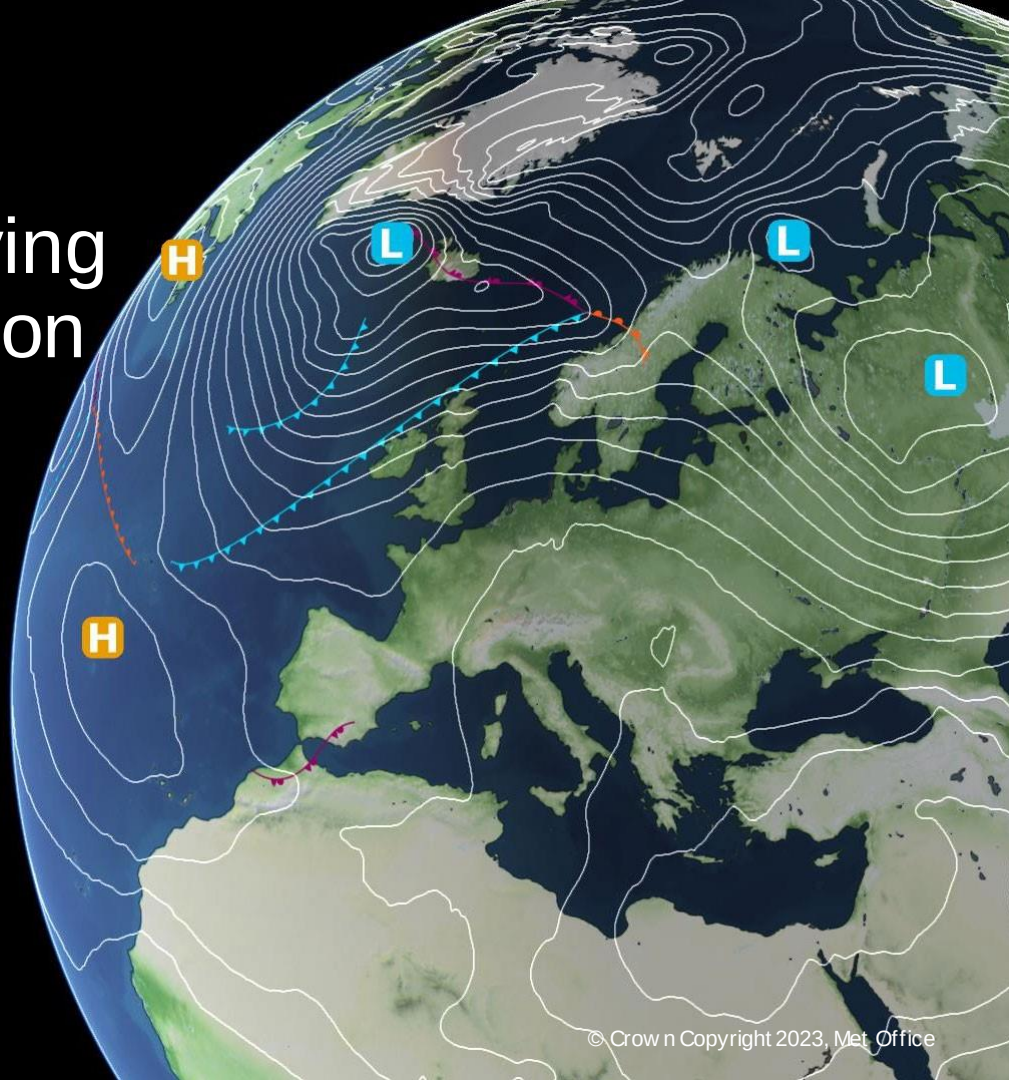
Experiences with improving standard legacy calibration process



Katherine Morris
Engineer, Radar R&D

Met Office

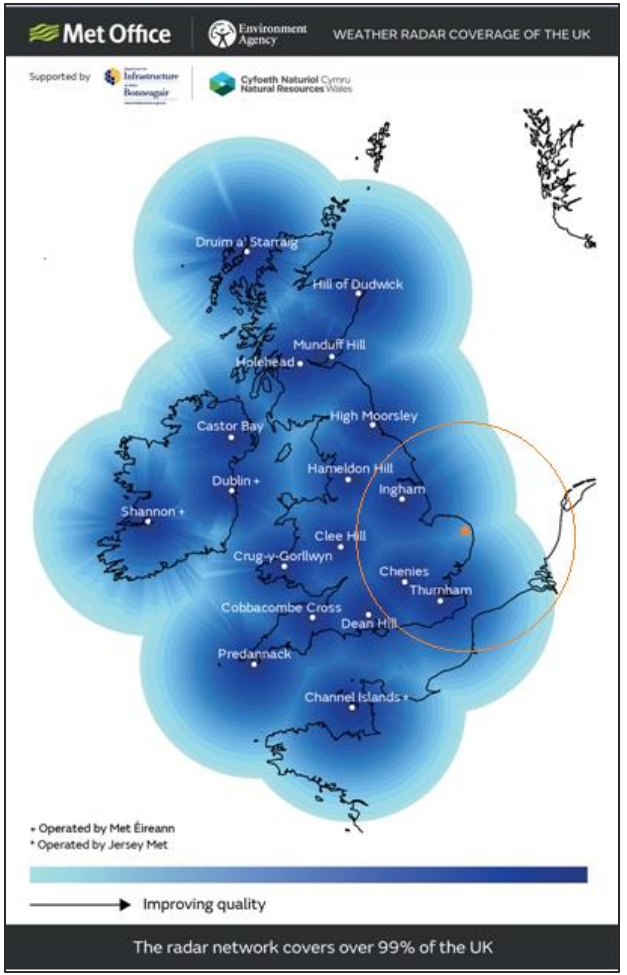
Overview

- Background
- Standard legacy calibration
- Motivation
- Improvements
- Challenges
- Further work

Met Office dual-pol radar

- 15* operational C-Band dual-pol radar:
  - In-house development (hardware and software)

- **Cyclops:** radar processing and control system



*Additional 3 radar contribute to UK composite, data supplied by: Jersey Meteorological Department & Met Éireann
Additional 1 Met Office radar in East Anglia in future

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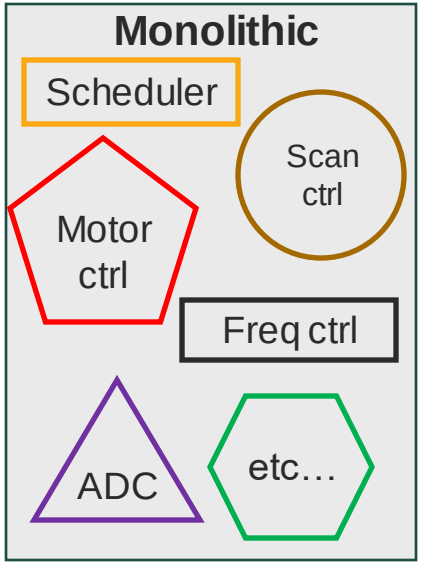
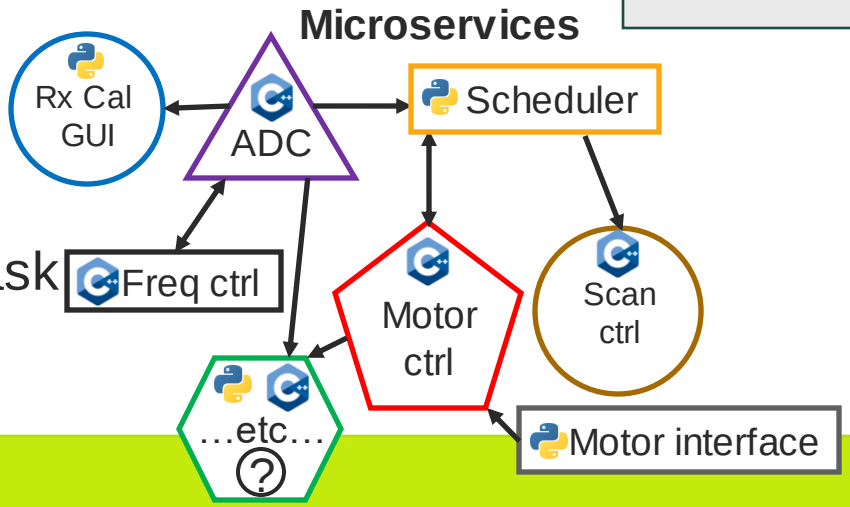
Cyclops

- Cross-platform: operational (Windows) & development (Linux)

- Microservices architecture
- Communicate by passing messages
- Language agnostic: use most appropriate language for the task





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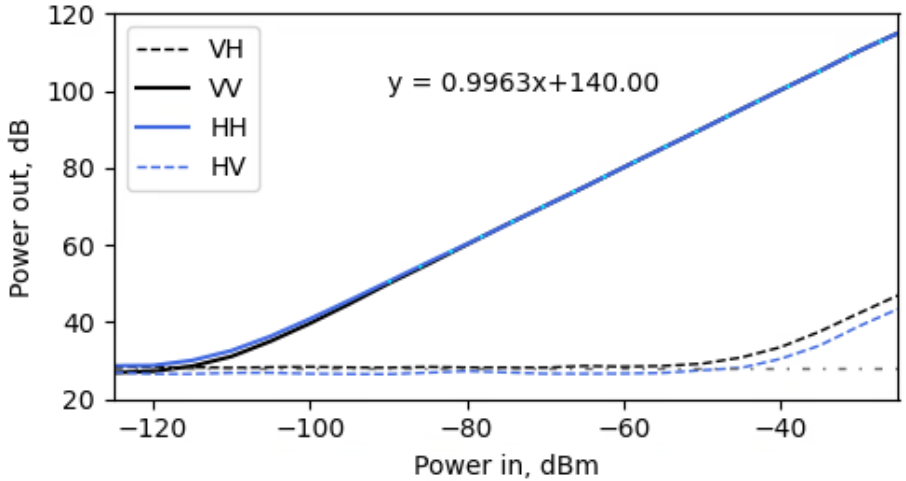
Standard legacy calibration

- Connect external* test signal generator (TSG)
- Inject known power across dynamic range
- Measure output power
- Calculate calibration factor (amplitude only)

- When?
  - 6 monthly – routine maintenance
  - After receiver component replacement



*Our radars do not have internal TSG

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Motivation

- Server upgrade required rework of existing applications
- Took the opportunity to improve where possible

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Old process

- Spreadsheet based
- Read off power values
- Manually type values
- Verification

- **Disadvantages:**
- Time-consuming
- Potential for errors
- Calibration at nominal frequency
- Rigid

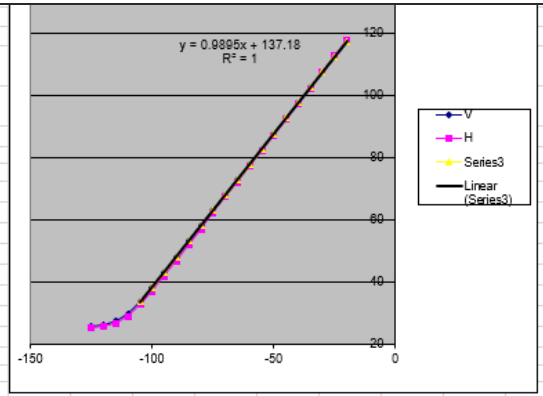
Site	Wardon Hill	Date	14/01/2022
Engineers	JH,SL,AH		
Receiver SM Badge No.	SM078791		

Coupler Loss	30	Cable Loss	1.4	Other Loss	0
Signal Generator Frequency		5.625			
Signal Generator Model and Badge No.		SM083361			
Signal Generator Calibration Date		12/04/2019			

LONG PULSE READINGS

Noise H at Start (Signal Generator Off)	24.8
Noise V at Start (Signal Generator Off)	25.4

Signal gen setting		Rx Output Long Pulse		Rx Output Long Pulse		Isolation			
		Input on V		Input on H					
dB in + losses	dB in	H	V	H	V	Isol V->H	Isol H->V	Gain V	Gain H
-93.6	-125	24.80	25.7	25.1	25.40	0.90	-0.30	-150.70	-150.10
-88.6	-120	24.80	26.2	25.6	25.40	1.40	0.20	-146.20	-145.60
-83.6	-115	24.80	27.4	26.6	25.40	2.60	1.20	-142.40	-141.60
-78.6	-110	24.80	29.8	28.9	25.40	5.00	3.50	-139.80	-138.90
-73.6	-105	24.80	33.6	32.6	25.40	8.80	7.20	-138.60	-137.60
-68.6	-100	24.80	38.1	37	25.40	13.30	11.60	-138.10	-137.00
-63.6	-95	24.80	43	41.9	25.40	18.20	16.50	-138.00	-136.90
-58.6	-90	24.80	48.1	46.8	25.40	23.30	21.40	-138.10	-136.80
-53.6	-85	24.80	53.2	51.7	25.40	28.40	26.30	-138.20	-136.70
-48.6	-80	24.80	58.3	56.8	25.40	33.50	31.40	-138.30	-136.80
-43.6	-75	24.80	63.10	62.30	25.40	38.30	36.90	-138.10	-137.30
-38.6	-70	24.80	67.80	67.30	25.50	43.00	41.80	-137.80	-137.30
-33.6	-65	24.80	72.60	72.10	26.00	47.80	46.10	-137.60	-137.10
-28.6	-60	25.00	77.50	77.10	26.30	52.50	50.80	-137.50	-137.10
-23.6	-55	25.60	82.60	82.10	27.70	57.00	54.40	-137.60	-137.10
-18.6	-50	26.90	87.60	87.15	30.40	60.70	56.75	-137.60	-137.15

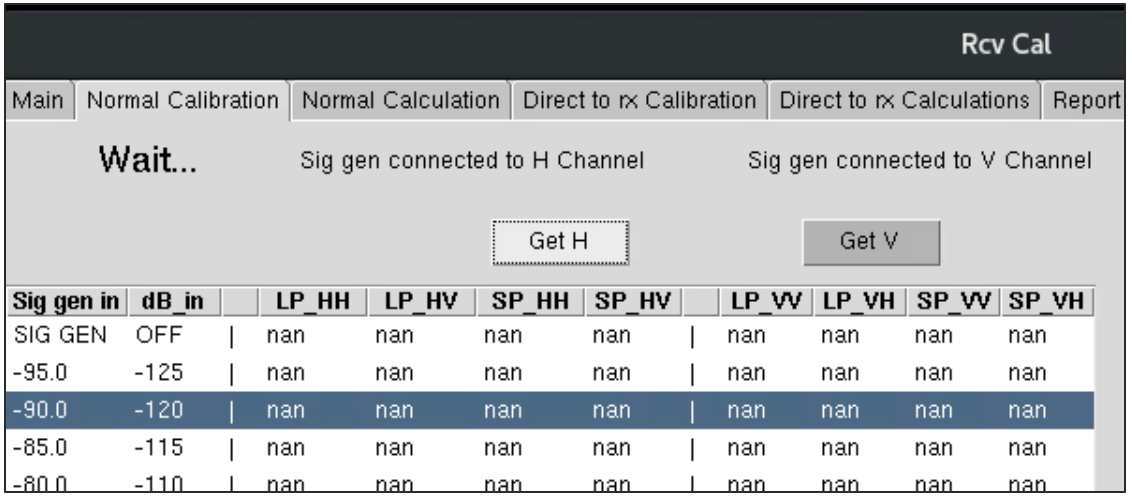


I_0 Average LP	-137.21
Radar Constant LDR_LP	70.3
Take Radar Constant from productconfig.txt	
Zo= RadarC + I_0	-66.91

Is the average gain difference okay?	
Is the linearity okay?	
Is the sensitivity okay?	
Is the isolation okay?	

New process

- Graphical User Interface (GUI)
- Python standard library + numpy + optional matplotlib



- Need to set up TSG with correct parameters
- Interfaces directly to Analogue-to-digital convertor (ADC)
- Automatically measures and stores power

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New process

- **Advantages**
- No manual data entry
- Reported to be 4-times faster
- Flexible

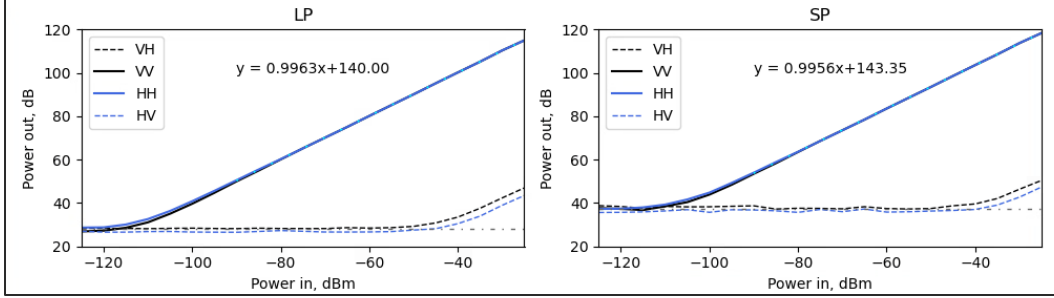
Rcv Cal

Main | Normal Calibration | Normal Calculation | Direct to rx Calibration | Direct to rx Calculations | Report

Sig gen connected to H Channel — Get H

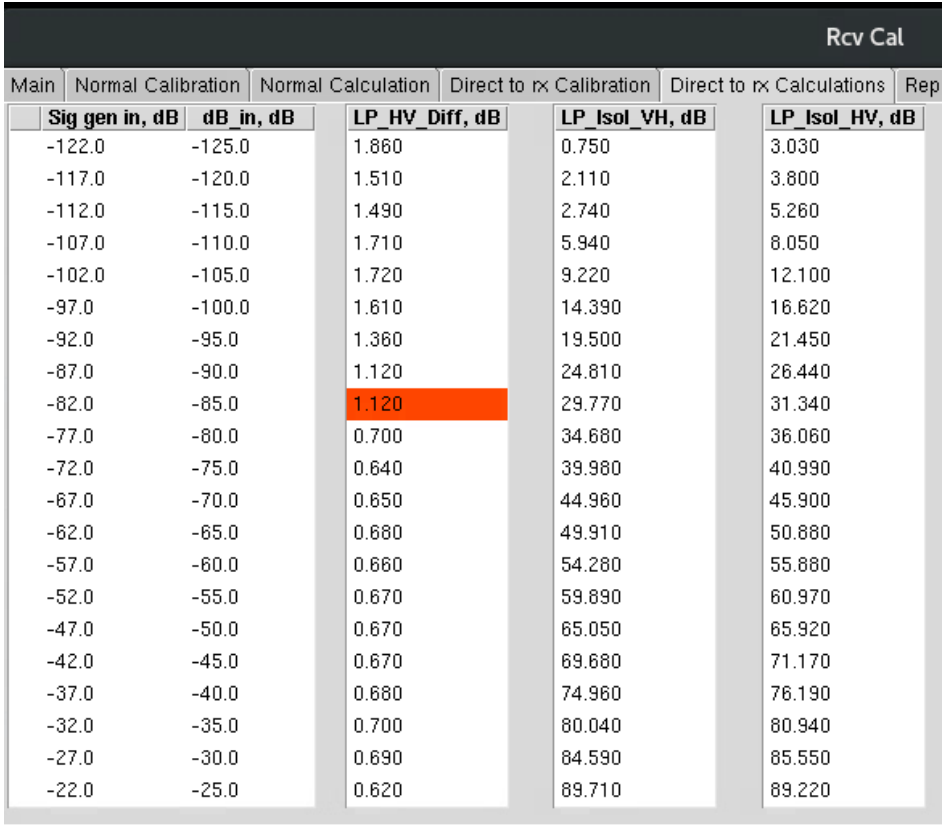
Sig gen connected to V Channel — Get V

Sig gen in	dB_in	LP_HH	LP_HV	SP_HH	SP_HV	LP_VV	LP_VH	SP_VV	SP_VH
SIG GEN	OFF	28.08	28.08	37.51	37.51	27.12	27.12	37.39	37.39
-92.0	-125	28.69	26.99	37.25	35.64	26.9	28.39	37.66	38.79
-87.0	-120	28.78	26.58	37.39	35.71	27.26	28.29	37.31	38.4
-82.0	-115	30.08	26.58	37.98	35.92	28.59	28.29	36.76	37.59
-77.0	-110	32.6	26.84	39.28	36.36	31.1	28.18	38.5	38.43
-72.0	-105	36.35	26.88	41.64	36.94	35.07	28.33	40.42	38.23
-67.0	-100	40.83	26.62	44.81	35.72	39.68	28.41	43.9	38.27
-62.0	-95	45.61	26.57	49.26	36.9	44.71	28.27	48.42	38.5
-57.0	-90	50.51	26.52	53.99	36.8	49.99	28.2	53.48	38.72
-52.0	-85	55.46	26.89	58.87	36.41	54.96	28.4	58.36	37.22
-47.0	-80	60.24	27.31	63.63	35.69	60.12	28.25	63.52	37.6
-42.0	-75	65.2	26.97	68.59	37.03	65.22	28.23	68.6	37.52
-37.0	-70	70.14	26.64	73.52	36.01	70.15	28.22	73.53	37.33
-32.0	-65	75.08	26.62	78.46	37.24	75.06	28.64	78.44	38.29
-27.0	-60	80.16	26.67	83.55	35.82	80.15	28.46	83.54	37.46
-22.0	-55	85.15	26.83	88.53	35.98	85.15	28.64	88.53	37.25
-17.0	-50	90.12	27.53	93.5	36.31	90.12	29.24	93.5	37.47
-12.0	-45	95.2	28.16	98.58	36.57	95.2	30.84	98.58	38.73
-7.0	-40	100.21	30.49	103.59	37.03	100.21	33.51	103.59	39.58
-2.0	-35	105.15	33.96	108.53	39.06	105.14	37.58	108.52	42.08
3.0	-30	110.36	38.96	113.74	42.71	110.33	42.35	113.71	46.36
8.0	-25	114.98	43.46	118.37	47.39	115	46.98	118.38	50.43



Verification

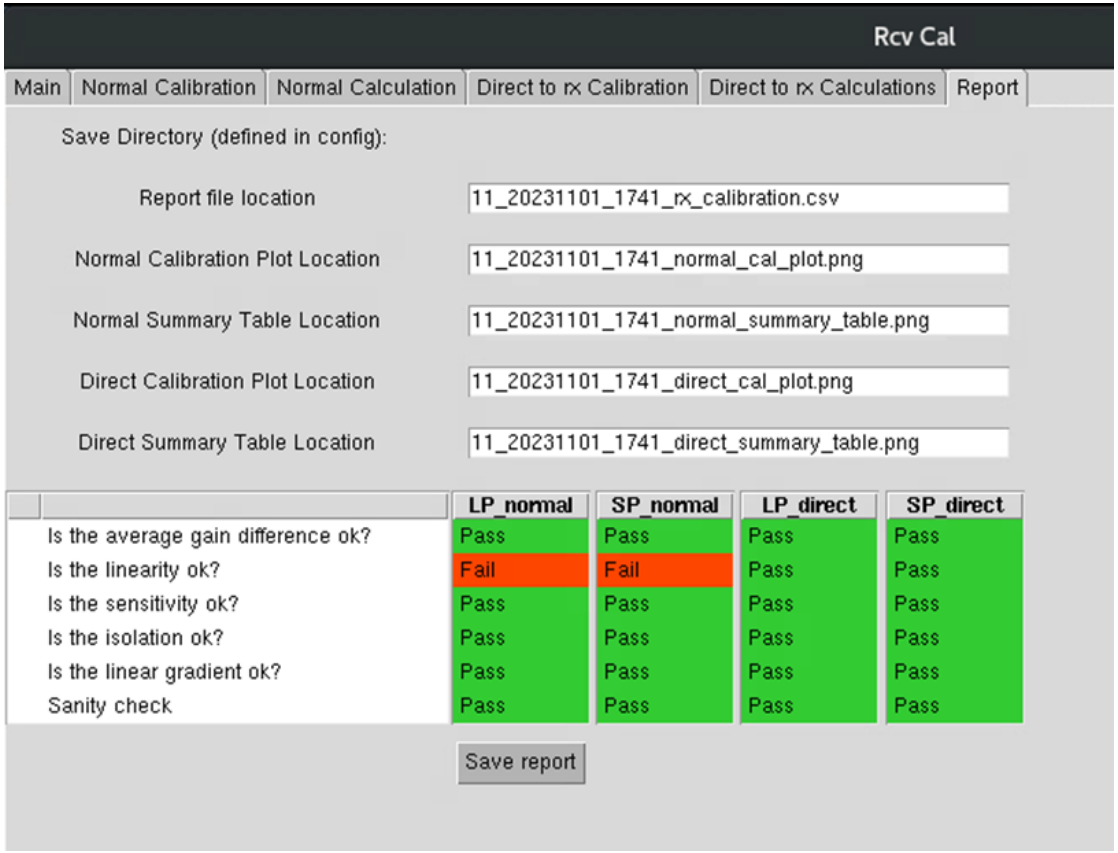
- Individual values
- Verification on:
  - Differential gain
  - Cross-channel isolation



Sig gen in, dB	dB_in, dB	LP_HV_Diff, dB	LP_Isol_VH, dB	LP_Isol_HV, dB
-122.0	-125.0	1.860	0.750	3.030
-117.0	-120.0	1.510	2.110	3.800
-112.0	-115.0	1.490	2.740	5.260
-107.0	-110.0	1.710	5.940	8.050
-102.0	-105.0	1.720	9.220	12.100
-97.0	-100.0	1.610	14.390	16.620
-92.0	-95.0	1.360	19.500	21.450
-87.0	-90.0	1.120	24.810	26.440
-82.0	-85.0	1.120	29.770	31.340
-77.0	-80.0	0.700	34.680	36.060
-72.0	-75.0	0.640	39.980	40.990
-67.0	-70.0	0.650	44.960	45.900
-62.0	-65.0	0.680	49.910	50.880
-57.0	-60.0	0.660	54.280	55.880
-52.0	-55.0	0.670	59.890	60.970
-47.0	-50.0	0.670	65.050	65.920
-42.0	-45.0	0.670	69.680	71.170
-37.0	-40.0	0.680	74.960	76.190
-32.0	-35.0	0.700	80.040	80.940
-27.0	-30.0	0.690	84.590	85.550
-22.0	-25.0	0.620	89.710	89.220

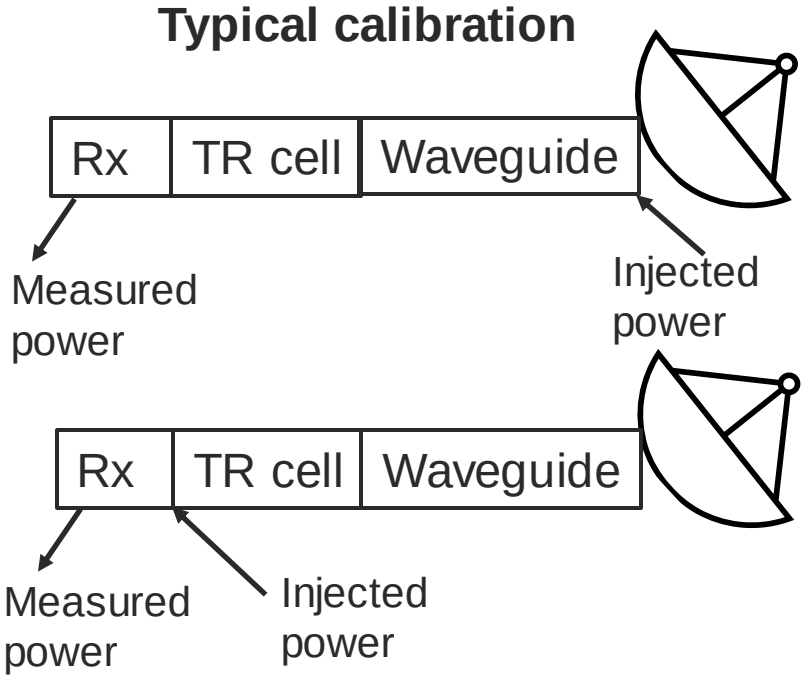
Verification

- Bulk check of all values
- Verification on:
  - Differential gain
  - Linearity
  - Sensitivity
  - Cross-channel isolation
- Configurable thresholds



Additional calibration

- Time saved → additional calibration sampling different path
- Comparing these isolates if signal loss is due to:
  - Degradation of receiver components
  - Degradation of waveguide or TR cell
    - Long-term monitoring → advanced warning of waveguide corrosion, issues with TR cell
    - Predictive maintenance



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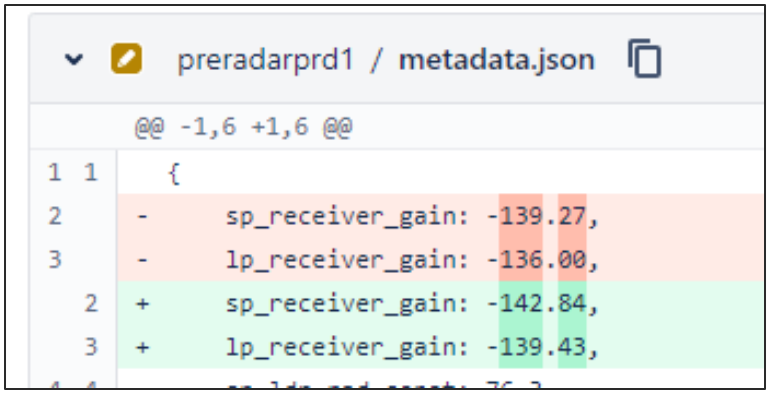
Version control in Git

- Site-specific calibration factor in Git
- Full traceability
- Further context in commit message
- Mandatory review by a Network Specialist



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Deployment with XLDeploy

- After review, deployment makes changes to site configuration
- Use a release automation software
- Full traceability
- Ability to roll-back changes

Package(s)	Type	User	State	Start Date	End Date
cyclops-config/cyclops-config-site-master-1012	Update	sandeep.san...	Done	Oct 31, 2023 - 9:54 AM	Oct 31, 2023 - 9:55 AM
cyclops-config/cyclops-config-site-master-1011	Update	paul.barnham	Done	Oct 27, 2023 - 2:25 PM	Oct 27, 2023 - 2:26 PM
cyclops-config/cyclops-config-site-master-1010	Update	sandeep.san...	Done	Oct 2, 2023 - 9:28 AM	Oct 2, 2023 - 9:29 AM
cyclops-config/cyclops-config-site-master-1006	Update	sandeep.san...	Done	Aug 24, 2023 - 9:59 ...	Aug 24, 2023 - 9:59 ...

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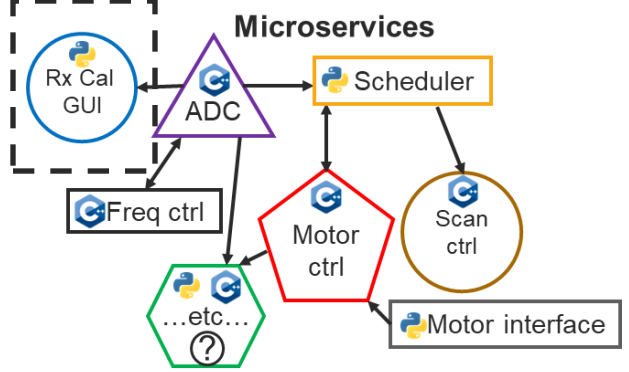
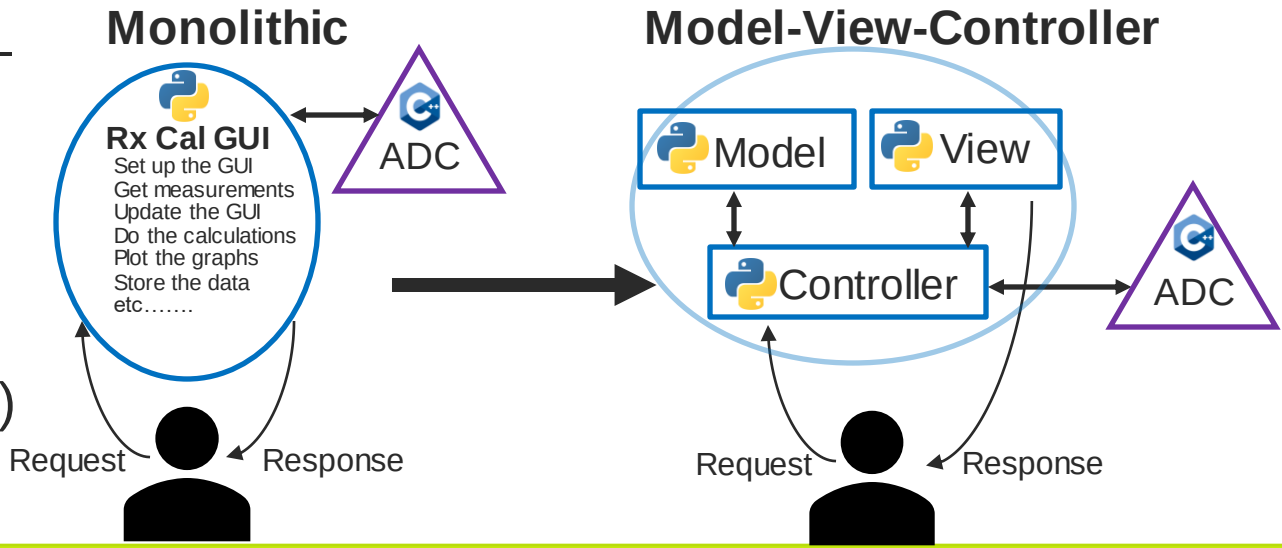
Challenges

- Monolithic → difficult to maintain.
- Integration with ADC – hardware

- **Solution:**
- Refactored to Model-View-Controller (MVC)





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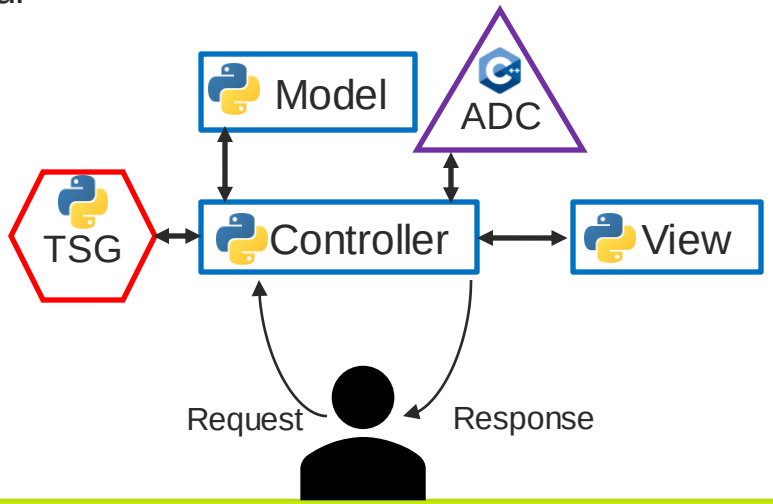
Quality Assurance

- Direct changeover to new process
- Model-View-Controller: more effective testing
- Quantitative assessment to confirm equivalence
- Incorporated user feedback throughout development
- User acceptance testing

Future work

- Planned:
  - Calibrate at actual site frequency (instead of nominal).
  - Revisit thresholds to make sure Fails are meaningful
- Planned, blocked:
  - Add interface to control TSG
  - Fully automate the process
  - Automatic monitoring → trend analysis



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Summary

- Significant improvement on previous process
- Opportunity for further improvements

- Software tools give us full traceability:
  - Version control, Git
  - Deployment, XLDeploy
- Possible with Python standard library and few dependencies
- Following software design principles makes it easier to maintain and implement new features