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Electrical and Sun calibration: what to trust when they disagree?

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*Frush (1984), Using the Sun as a calibration aid in multiple parameter radar , 22nd Conf. on Radar meteorology, AMS, Preprints, Zurich, CH, pages 306-311.

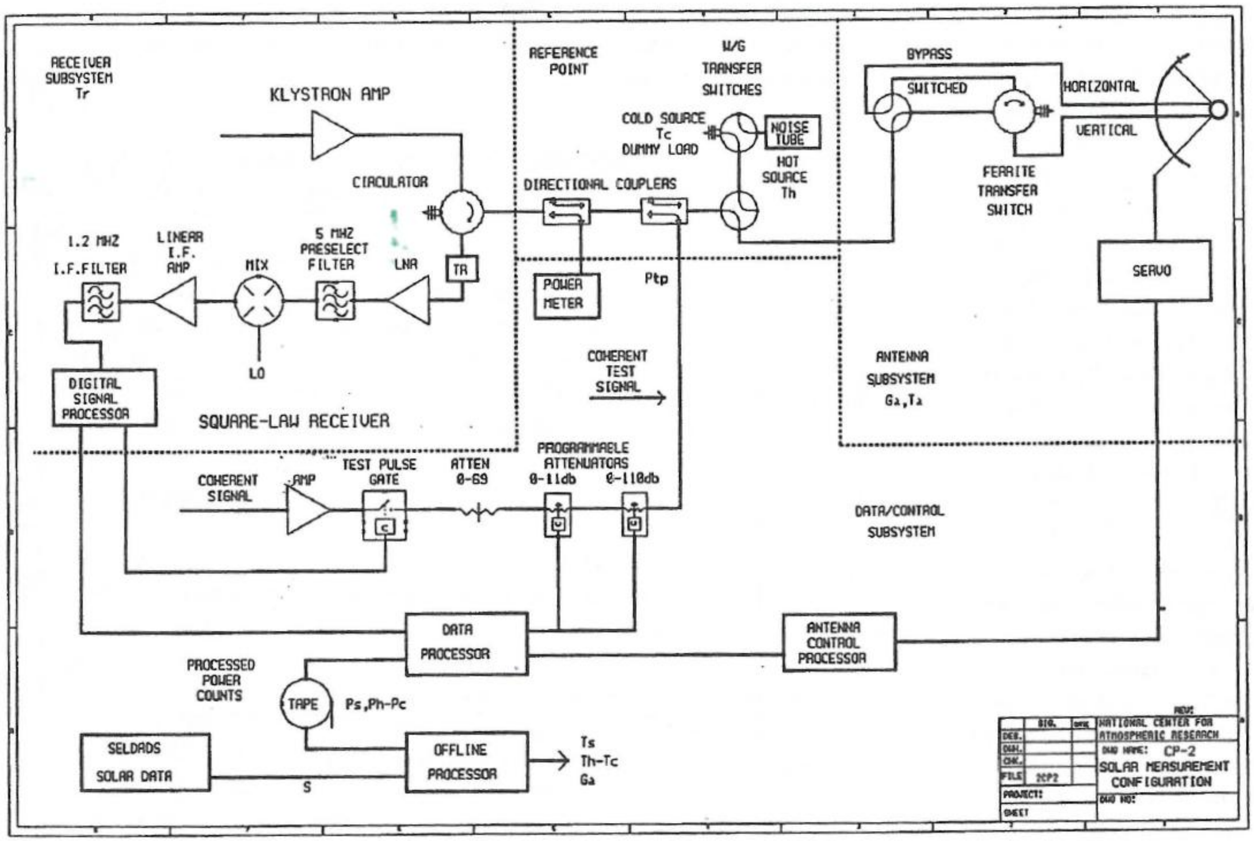


Figure 1. CP-2 solar measurement configuration has permanently installed noise sources, directional couplers, waveguide switches, programmable attenuators, and data processing/recording/antenna control software.

* The National Center for Atmospheric Research is sponsored by the National Science Foundation.

Antenna beam axis pointed at the Sun center. Each meas. ~ 20 min

They were able to quantify the incoming flux by comparing it with NS ref.

From average Solar power in analog-digital-units to incident spectral Irradiance in $W/(m^2 \cdot Hz)$

- $P_{refp} = NS_{refp} + P_{out} - NS_{out}$ (1)

where $[NS_{refp}] = [P_{refp}]$ = dBm, while $[NS_{out}] = [P_{out}]$ = dBadu.

By way of example, let us assume the stable NS_{refp} to be -91 dBm;

let P_{out} be 23.0 dBadu both days, while NS_{out} 33.0 and 33.1 dBadu, respectively.

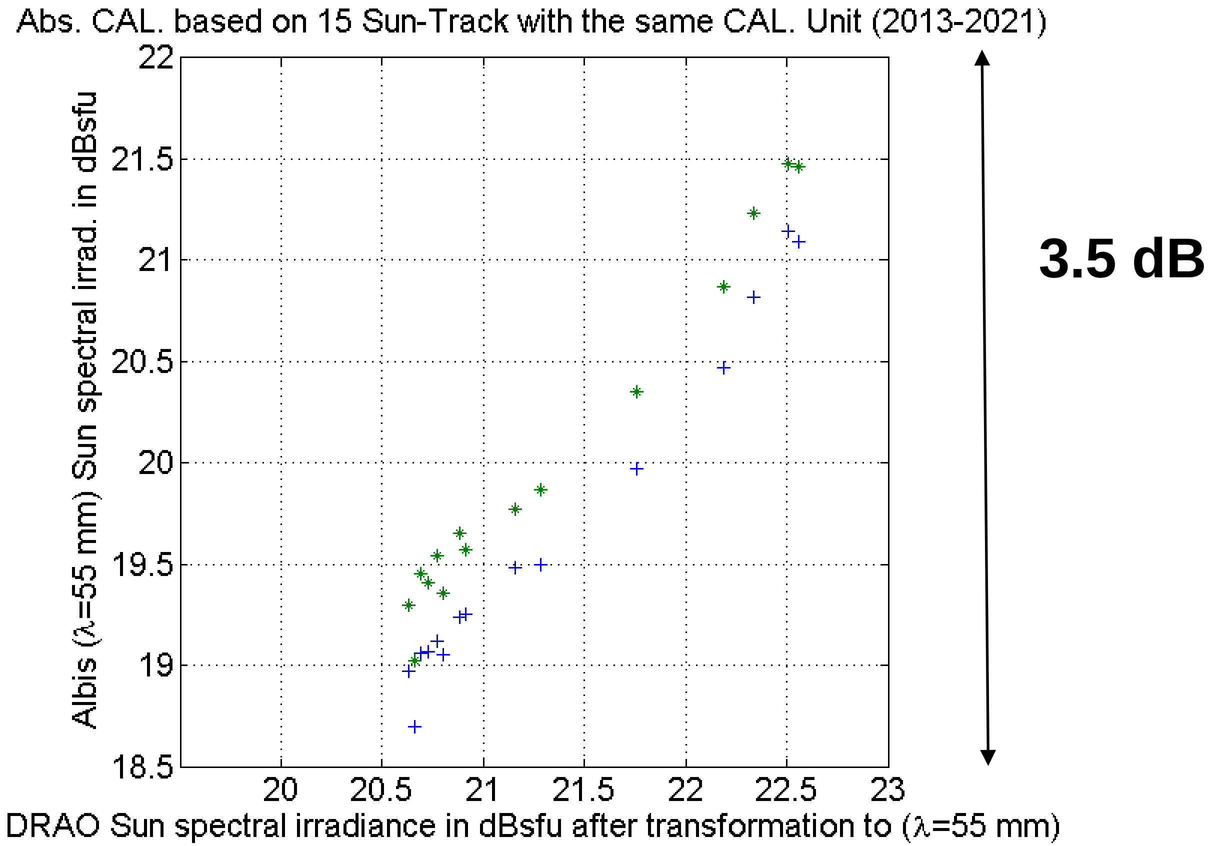
Then P_{refp} = -101.0 and 100.9 dBm, respectively.

- $P_{ant} = P_{refp} + L_{Rx} + 3\text{ dB} + L_{nps}$ (2)
- $I_{5.5} = P_{ant} + 190\text{ dB} - B_{dBHz} + 10\,Log\left(\frac{4\pi}{\lambda^2}\right) - G_{dB}$ (3)

$[I_{5.5}]$ = dBsfu for both **H** and **V**

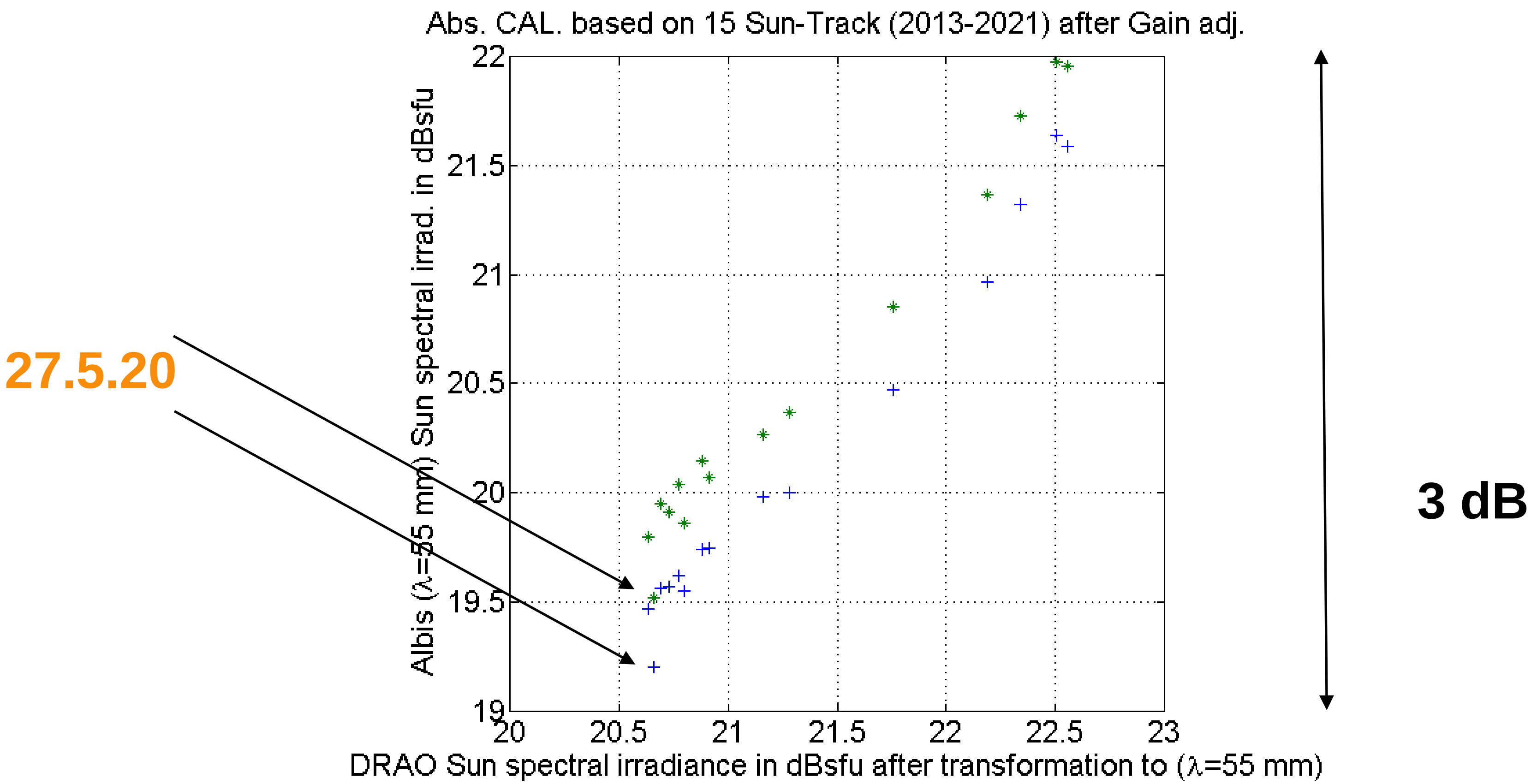
where 1 SFU is equal to $10^{-22}\ W \cdot m^{-2} \cdot Hz^{-1}$, which is $10^{-19}\ mW \cdot m^{-2} \cdot Hz^{-1}$.

Details in Gabella M., 2015: Checking **Absolute Calibration** of V and H polarization …, *J. Electr. Eng*., **3**, 163-169.



Albis radar : the longest series of accurate Sun-Tracks for absolute Rx CAL.

N.B. Acceptable 1-dB offset (underest.) already accounted for (45˚ ideal line)



Albis Sun-Tracks and **absolute Rx CALIBRATION**: results after **0.5 dB Gain adj.**

N.B. Acceptable 1-dB offset (underest.) already accounted for (45˚ ideal line)

PPM radar, 2397 m: Sun-track, new CAL. Unit. All values in dBsfu

ΔH and ΔV represents the multiplicative "error" with respect to DRAO

Date	DRAO	H_{NSub}	V_{NSub}	ΔH	ΔV
28 June 2016	20.80 ± 0.031	20.05	20.15	-0.75 dB	-0.65 dB
24 May 2017	20.88 ± 0.033	19.97	20.06	-0.91 dB	-0.82 dB
20 August 2018	20.63 ± 0.022	19.53	19.51	-1.10 dB	-1.12 dB
19 February 2019	20.69 ± 0.015	19.37	19.47	-1.32 dB	-1.22 dB
20 January 2020	20.73 ± 0.012	19.91	20.00	-0.82 dB	-0.73 dB
5-date relative differential bias μ±σ				-0.07±0.05 dB	
Average of 5 dates	20.75	19.77	19.84	-0.98±0.23	-0.91±0.25
27 May 2020	20.71 ± 0.124	18.88	19.28	-1.83 dB	-1.43 dB
Average of 6 dates	20.74	19.62	19.74	-1.12±0.41	-1.00±0.31
6-date relative differential bias μ±σ				-0.13±0.15 dB	

H-V= -0.40 dB

Performance of Swiss radars with original CAL. Units: Gabella et al. (2016) Atmosphere

PPM and Lema Sun-track, new CAL. Units

Date	DRAO	H_{NSub}	V_{NSub}	ΔH	ΔV
PPM 28 June 2016	20.80 ± 0.031	20.05	20.15	-0.75 dB	-0.65 dB
PPM 24 May 2017	20.88 ± 0.033	19.97	20.06	-0.91 dB	-0.82 dB
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PPM 20 Jan. 2020	20.73 ± 0.012	19.91	20.00	-0.82 dB	-0.73 dB
PPM 27 May 2020	20.71 ± 0.124	18.87	19.28	-1.84 dB	-1.43 dB
Lema 20 January 2020	20.73 ± 0.009	20.77	20.78	+0.04 dB	+0.05 dB
Lema 28 May 2020	20.64 ± 0.077	20.02	19.90	-0.62 dB	-0.74 dB
Lema 17 Sep. 2021	20.77±0.003	21.04	20.88	+0.27 dB	+0.11 dB

Noise Subtraction at C-band is ~0.7 dB for a quiet Sun

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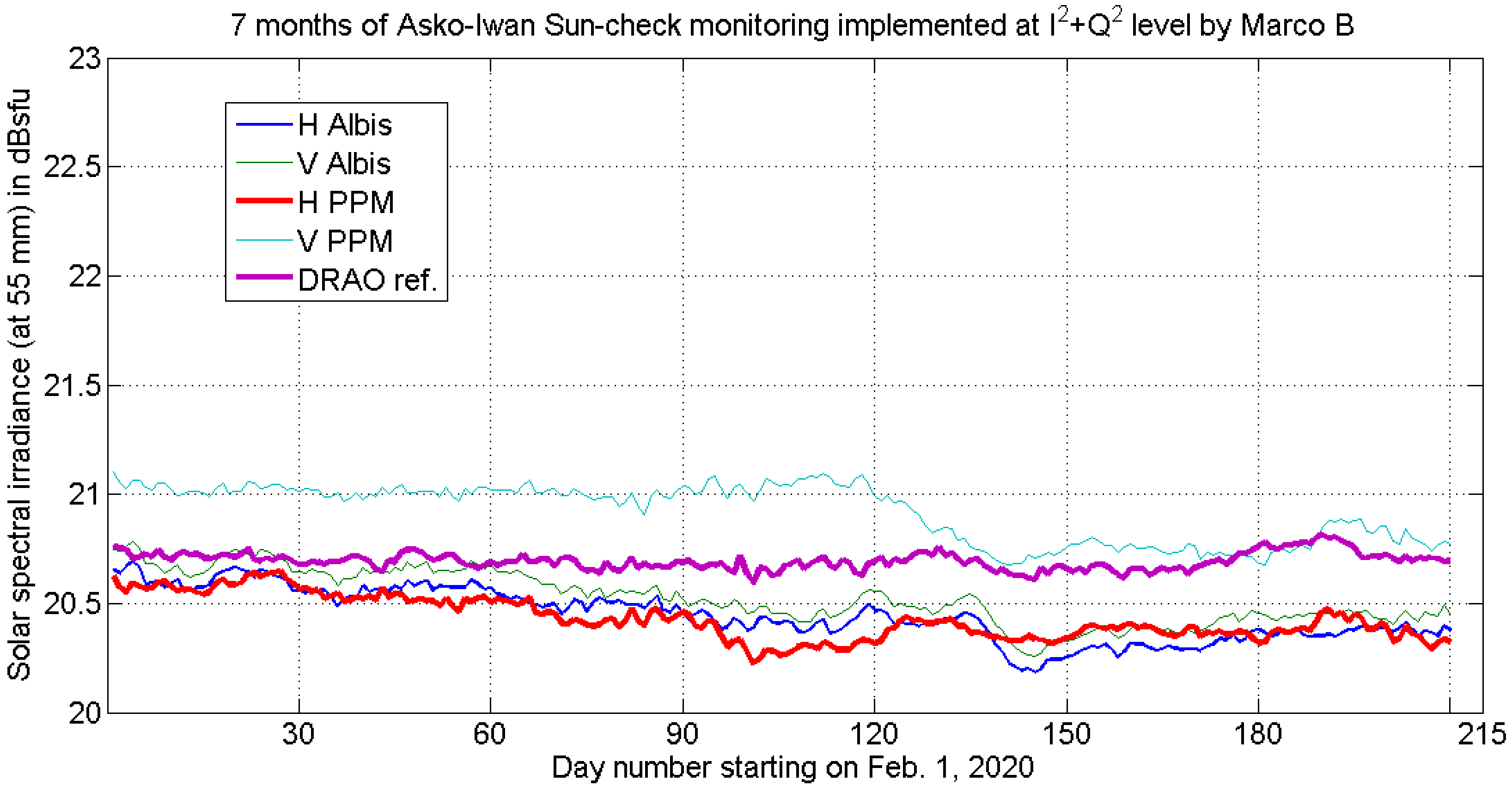
PPM 27 May 2020	20.71 ± 0.124	18.87	19.28	-1.84 dB	-1.43 dB
PPM 30 Sep. 2021	21.37 ± 0.094	20.34	20.37	-1.03 dB	-1.00 dB
Lema 20 January 2020	20.73 ± 0.009	20.77	20.78	+0.04 dB	+0.05 dB
Lema 28 May 2020	20.64 ± 0.077	20.02	19.90	-0.62 dB	-0.74 dB
Lema 17 Sep. 2021	20.77±0.003	21.01	20.967	+0.24 dB	+0.20 dB

Swiss radars underestimation with original CAL. Units: Gabella et al. (2016) Atmosphere

Daily Sun-Check confirms a tendency to underestimate in summer: a "sort of annual" fluctuations of some Swiss radars if compared to the Sun



Absolute Calibration error: μ±σ relative to DRAO

Radar	# of samples	ΔHor.	Δvert.
WEI, original CAL. Unit	9+2	-0.70±0.30 dB	-0.84±0.20 dB
WEI, 2nd CU, +27May2020!	6+1!	-0.97±0.31 dB	-1.10±0.25 dB
WEI, 3rd CU, what to do?	3	-1.41±0.15 dB	-0.67±0.17 dB
Lema, original CAL. Unit	6+4	-0.78±0.20 dB	-0.87±0.24 dB
Lema new CU, +28May2020!	2+1!	-0.10±0.46 dB	-0.19±0.47 dB
Albis ☺ original CU+29May20!	7+7+1!	-1.16±0.14 dB	-0.80±0.15 dB
PPM, new CU, +27May2020!	6+1!	-1.01±0.48 dB	-0.90±0.38 dB
Dole 2nd CAL. Unit, 24.6.2020	1	-0.38 dB	-0.36 dB

Performance of Swiss radars with original CAL. Units: Gabella et al. (2016) Atmosphere

Absolute Calibration error: μ±σ relative to DRAO

Radar	# of samples	ΔHor.	Δvert.
WEI, original CAL. Unit	9+2	-0.70±0.30 dB	**-**0.84±0.20 dB
WEI, 2nd CU	6	-0.86±**0.10 dB**	-1.01±**0.11 dB**
WEI, 3rd CU, without 30.9.2021	3	**-0.41**±0.15 dB	**-0.37**±0.17 dB
Lema, original CAL. Unit	6+4	-0.78**±0.20** dB	-0.87**±0.24** dB
Lema new CU	2	**+**0.15±(0.16) dB	**+**0.08±(0.04) dB
Albis ☺ original CAL. Unit	7+7	-1.14±0.**12** dB	-0.**78**±**0.13** dB
PPM, new CU (30Sep21?)	6	-0.87±**0.34** dB	-0.81±**0.33** dB
Dole 3rd CAL. Unit, 26.5.2020	1	+0.08 dB	+0.24 dB

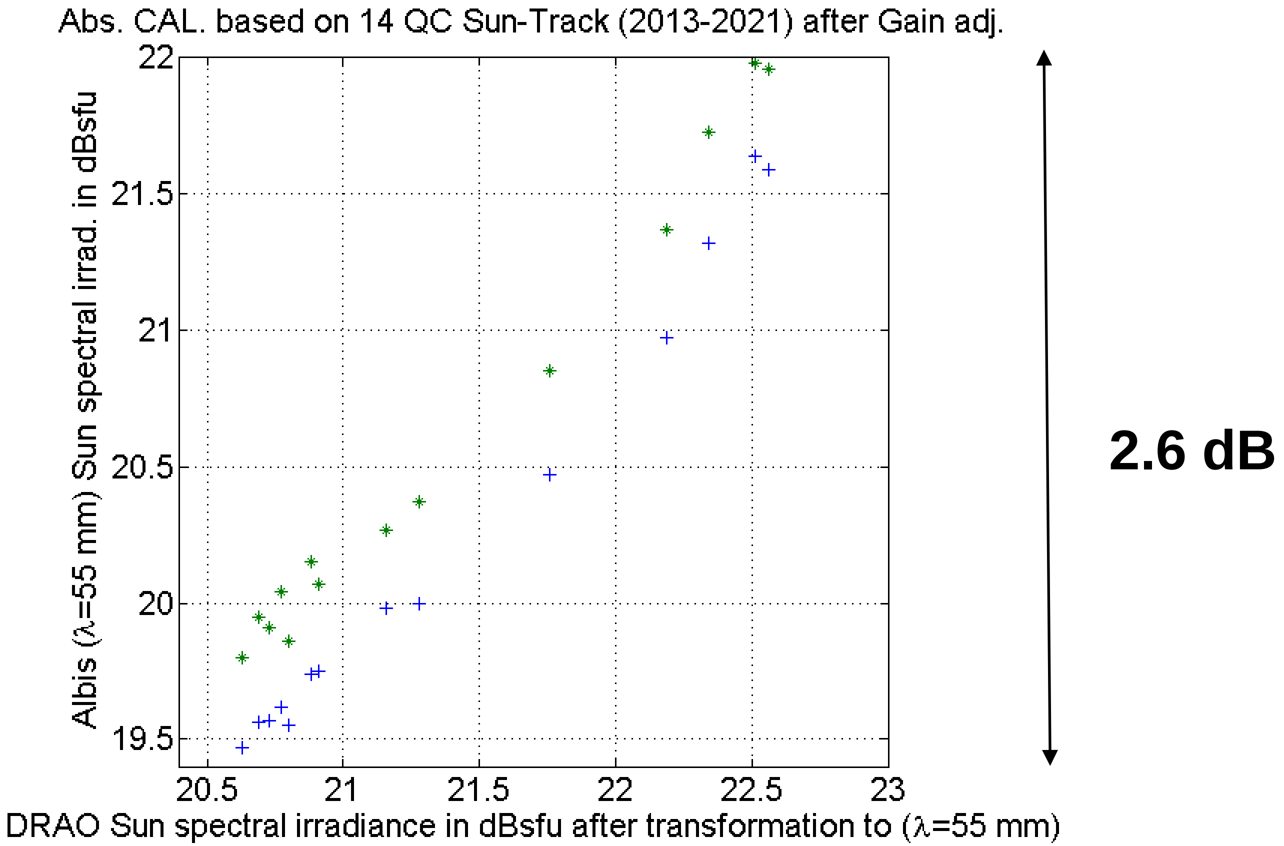
Noise Subtraction at C-band is ~0.7 dB for a quiet Sun

WEI radar, 2850 m: 3rd CAL. Unit, 2021

Date	DRAO	H_{NSub}	V_{NSub}	ΔH	ΔV
11 Feb. 2021	20.76 ± 0.067	19.45	20.23	-1.31 dB	-0.53 dB
27 Apr. 2021	20.94 ± 0.022	19.60	20.31	-1.34 dB	-0.63 dB
10 June 2021	20.84± 0.057	19.26	19.98	-1.58 dB	-0.86 dB
3-date relative differential bias μ±σ				-0.74±0.04 dB	
Average of 3 dates	20.85	19.44	20.17	-1.41±0.15	-0.67±0.17
Q. What to do? Trust the Sun?					

ΔH and ΔV represents the multiplicative "error" with respect to DRAO

Answer: Yes, changing Noise Source reference by +1.0 dB and +0.3 dB, respectively!



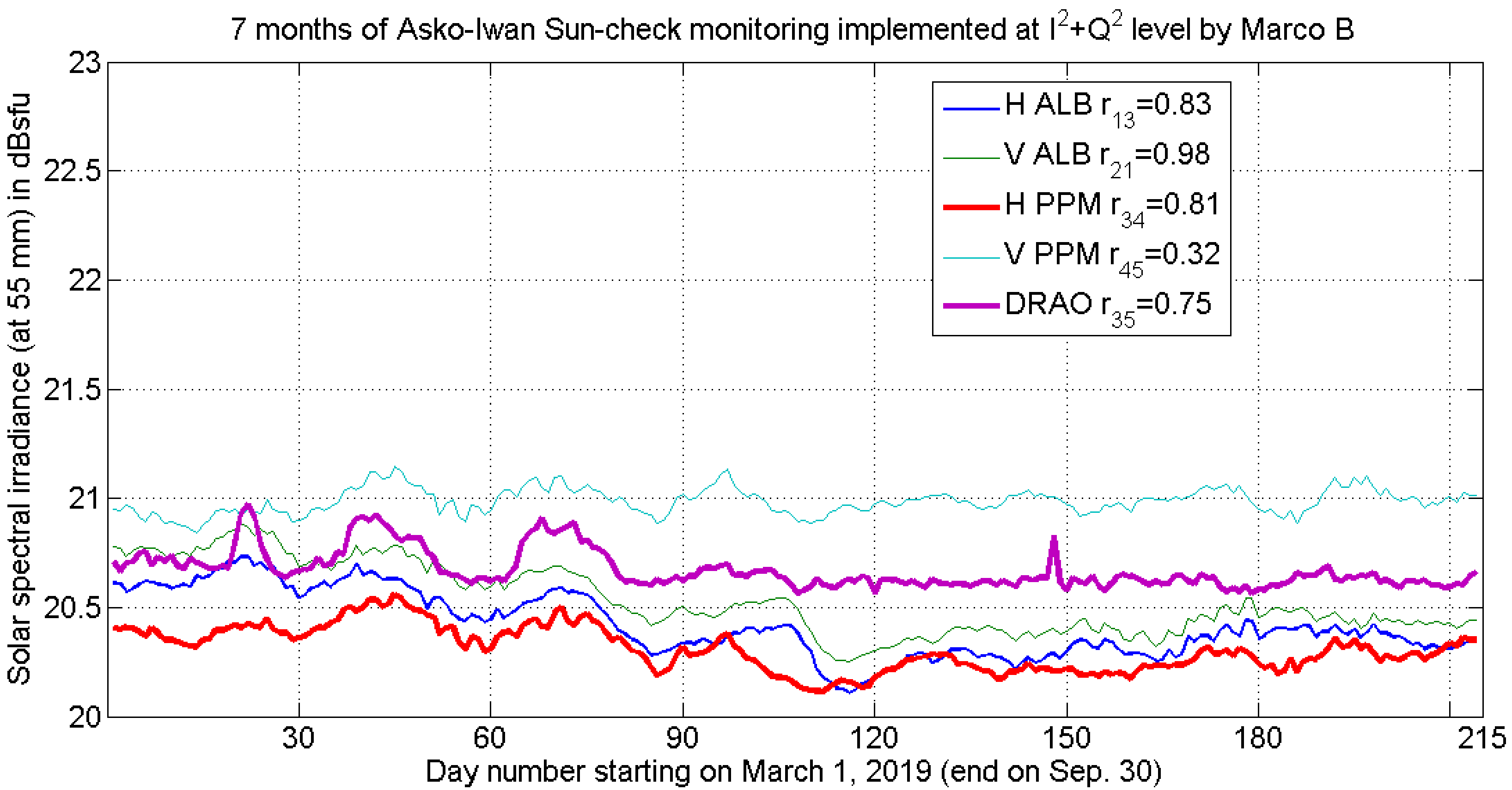
Absolute Rx CALIBRATION: Albis results after **0.5 dB Gain adj.**

N.B. Acceptable 1-dB offset (underest.) already accounted for (45˚ ideal line)

Summary and conclusions

- The EM power that comes from the Sun is an effective and cost/benefit wise reference for checking the quality of weather radar receivers worldwide.
- Sun tracking (~20 minutes, 1989) comparison between DRAO ref. and NCAR radar at S-band. Focus on relative calibration (14 observations, single-pol).
- Sun Tracking (~2 minutes) for the 5 Swiss C-band radars (31 obs., 2013-2016) ABSolute calibration. Average error of all (but Albis radar) dual-pol Rx between -0.4 and -1.0 dB. **DRAO reference extrapolated to C-band**. Albis corrected (Antenna Gain). WEI corrected (Noise Source reference value)
- **DRAO is far in time (18, 20, 22 UTC), space (West of Canada) and spectrum (107 mm vs 55 and 53 mm…)**
- **→ Clear need and opportunity to build a centimeter Sun observatory in Europe.**

Grazie, o Asko!



Daily Sun-Check confirms a tendency to underestimate in summer:
a “sort of annual” fluctuations of some Swiss radars if compared to the Sun

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Agreement with DRAO in terms of correlation

Radar	Degrees of freedom	Raw H	Raw V	Hor_{NSub}	$Vert_{NSub}$
WEI	8	93.7%	94.0%	94.1%	94.1%
Lema	5	97.3%	97.3%	96.7%	**96.9%**
Albis	6	97.6%	98.7%	98.3%	**99.0%**
X-band, Feb. 2-Mar. 20, 2016	14	66%	**75%**	39%	48%
X-band, Mar. 21-May 15, 2016	14	35%	**60%**	31%	57%
X-band, May 16-Aug. 30, 2016	14	76%	**87%**	68%	85%