

AWS Lunar Observations and Pointing, Beam, and Inter-Channel Performance Assessment

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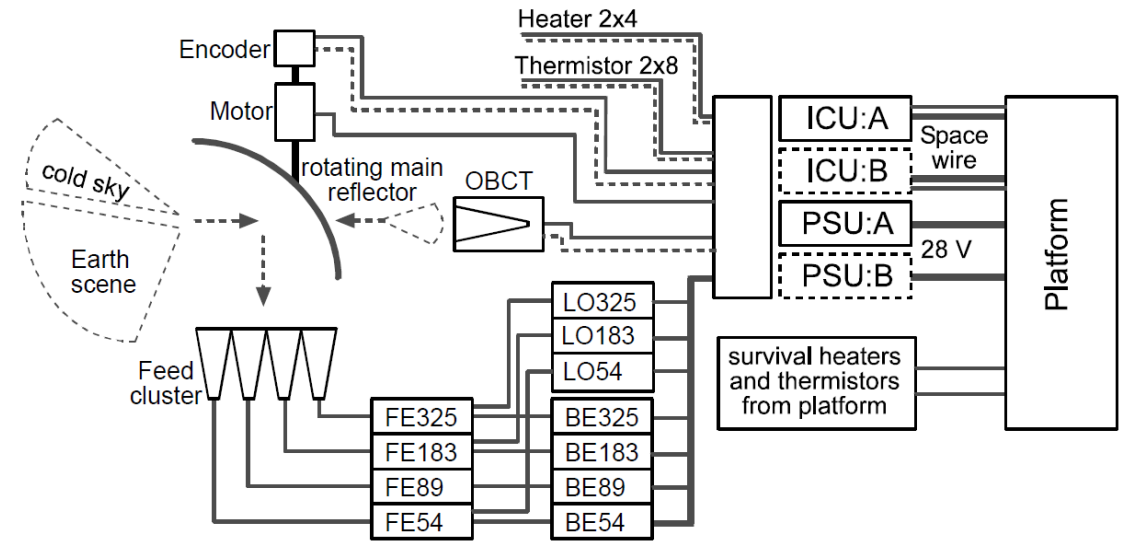
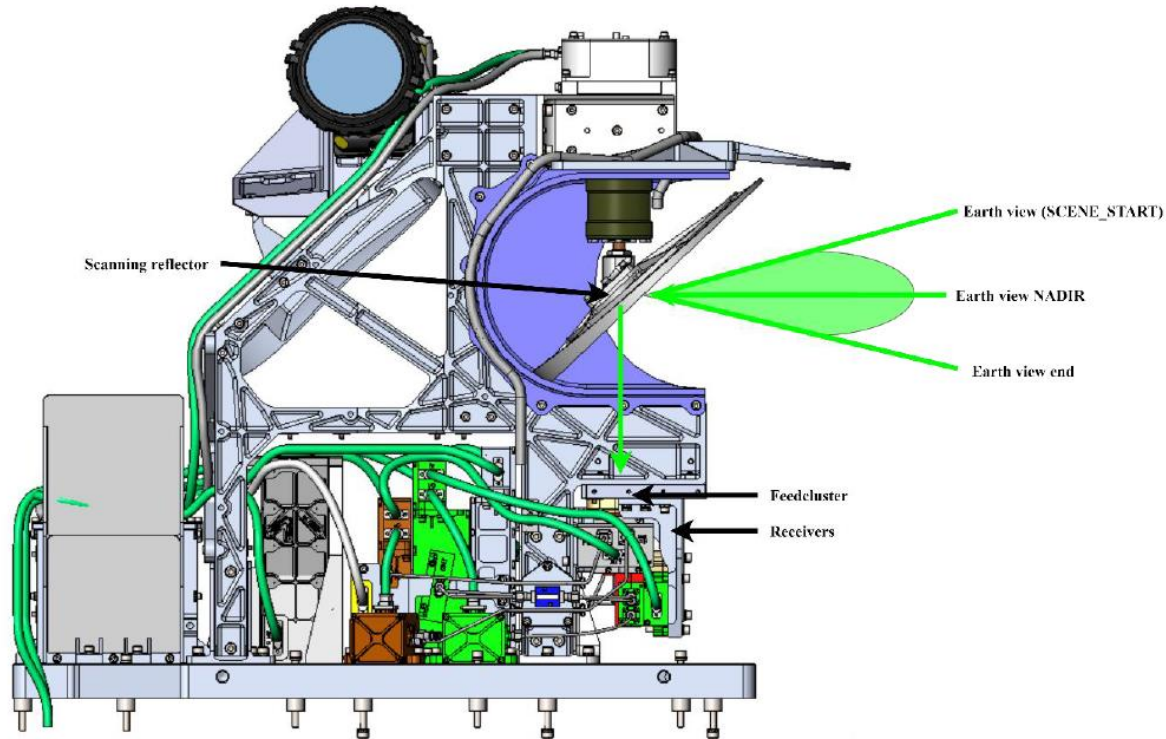
Fudan University

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- Pointing direction calculation
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Background

- AWS was launched in 2024: ~120 kg, ~600-km orbit, 97-min period, and three-day revisit.
- Its MWR scans cross-track, viewing Earth, cold space, and an onboard blackbody.
- **A rotating antenna focuses radiation onto four feed horns and receivers.**
- Lunar intrusion into the cold-sky FOV creates a brief, stable external-reference peak.



Channels in the Same Group Share One Feed Horn

AWS MWR Parameters

The four channel groups cover 54, 89, 165/183, and 325 GHz. Channels in the same group share one feed horn and therefore have the same pointing direction.

Channel Group	Chan nel	Frequency (GHz)	Bandwidth (MHz)	FWHM (°) max/min/mean	Main-Beam Efficiency (%)
1	1	50.293	168	3.55/2.92/3.24	96.4
	2	52.789	378		
	3	53.249	283		
	4	53.592	359	3.46/2.81/3.13	96.6
	5	54.386	384		
	6	54.920	377		
	7	55.501	322		
	8	57.297	295	3.34/2.71/3.03	96.9
2	9	89.135	3547	1.99/1.64/1.81	96.8
3	10	165.383	2882	1.05/0.90/0.97	96.4
	11	176.488	1783		
	12	178.947	1714	0.97/0.86/0.92	96.8
	13	180.289	993		
	14	181.466	920		
	15	182.313	453	0.97/0.86/0.92	96.6
4	16	326.37, 323.95	855, 849	1.05/0.92/0.98	98.0
	17	327.47, 322.92	1273, 992		
	18	329.29, 320.96	2063, 2107	1.06/0.93/0.99	97.9
	19	331.60, 318.71	2461, 2416		

Note: FWHM values are ground measurements; channels 16–19 are double-sideband channels.

The main objective is to determine how AWS lunar observations can be used for calibration.

- How can lunar observations determine the pointing angle?
- How to fit along-track FWHM?
- How can cross-track FWHM and the FOV-to-Moon-center offset be obtained?
- How can random variability in MWR observations be suppressed?
- What causes large antenna-temperature differences among nearby-frequency channels with the same pointing?
- How can these differences be removed for inter-channel calibration?

Pointing Direction Calculation

Satellite position, velocity, and satellite-to-Moon vectors in the ICRF frame are from STK software. The satellite coordinate system (x, y, z) is defined using the velocity vector as x and the Earth-to-satellite vector as z.

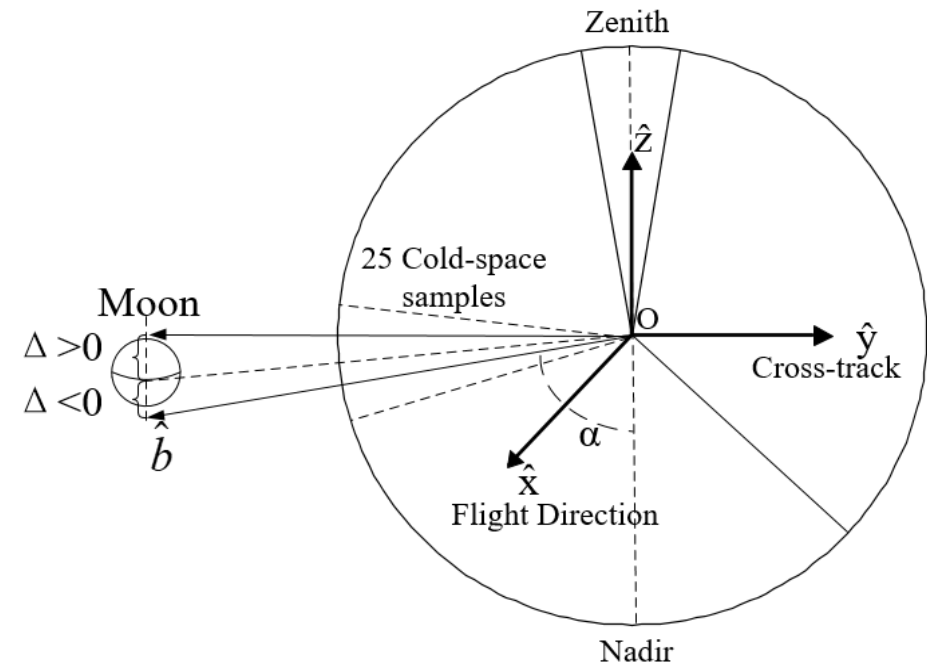
Pointing: $\hat{b}(t) = -\sin \alpha \hat{y}(t) - \cos \alpha \hat{z}(t)$

Angle: $\theta(t) = \cos^{-1} [\hat{b}(t) \cdot \hat{s}_m(t)]$

FOV Angle Conversion (Tim Hewison, GSICS subgroup meeting, 2026):

$$\alpha = \frac{N}{45000} \times 360^\circ$$

The FOV-to-Moon-center angle θ is calculated; the Moon is closest to the cold-sky FOV when θ reaches its minimum.



AWS Cold-Sky Pointing Geometry

α Correction

Figs. 5(a) and 5(b) show the corresponding FOV-to-Moon angle θ . Using the α from the data records cannot reproduce the lunar observation time as the count map (red line). Correction on α is performed so that the reproduced lunar observation time is consistent with the count data for lunar observation event from different date (black line).

For lunar observations around July 15, 2025, the $\Delta\alpha$ corrections are AWS1 $+0.18^\circ$, AWS2 $+2.5^\circ$, AWS3 -1.4° , AWS4 -2.2° .

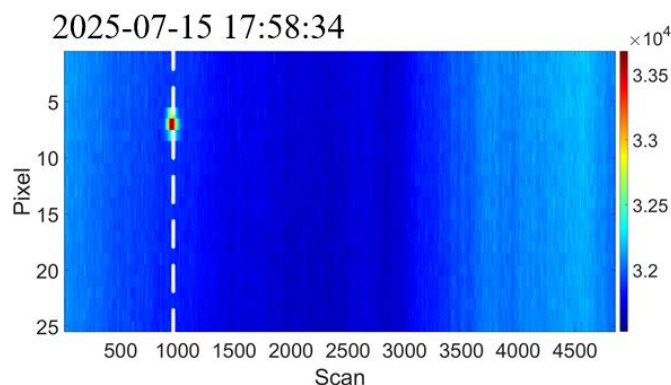


Fig. 4(a) CH14 Lunar Observation at 17:58:34

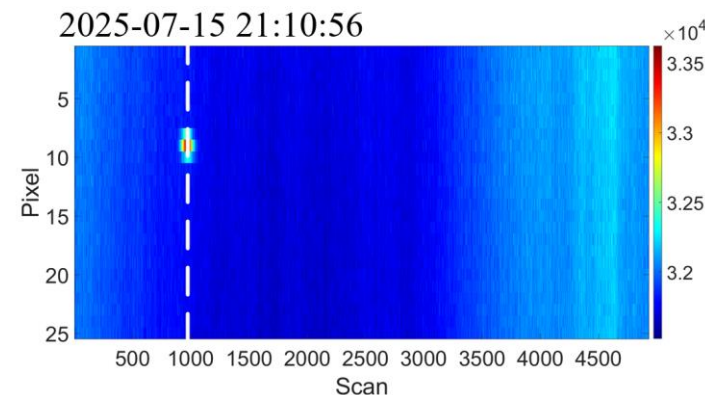


Fig. 4(b) CH14 Lunar Observation at 21:10:56

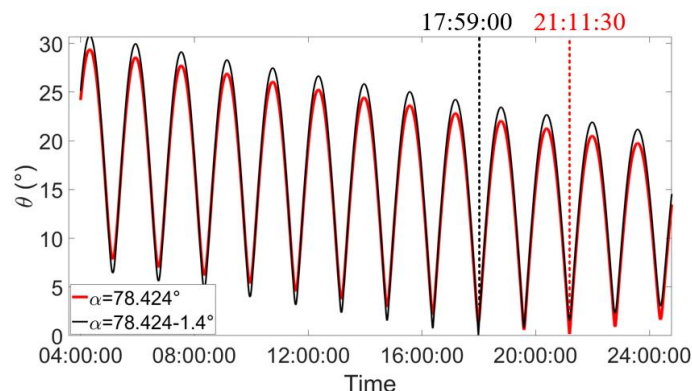


Fig. 5(a) α Correction: θ versus Time

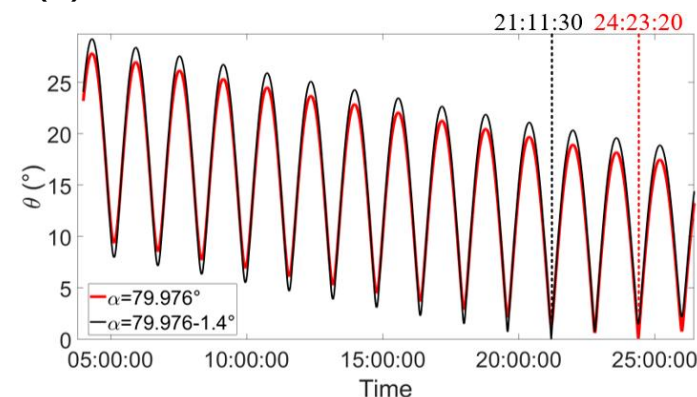


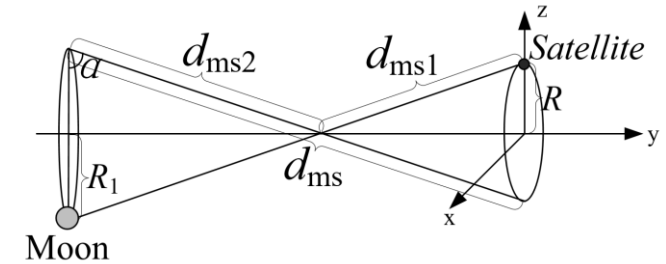
Fig. 5(b) α Correction: θ versus Time

Along-Track FWHM Fitting

Fitting Equation (Burgdorf et al., 2019):

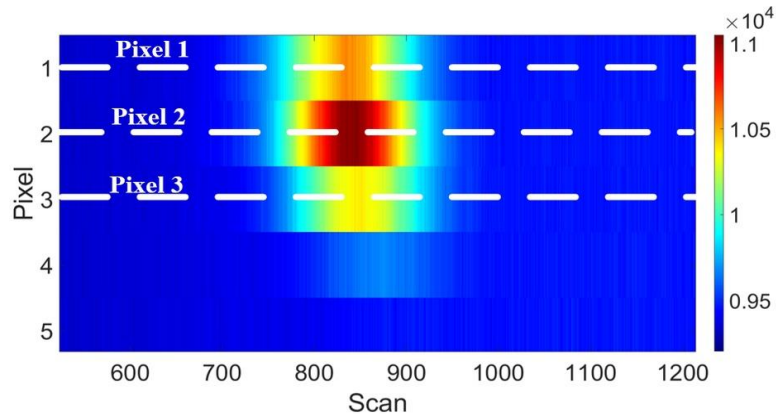
$$FWHM_x = \frac{2\pi R_1}{T_P} \cdot \frac{T_F}{d_{ms}}$$

- T_F : FWHM duration = scans $\times$ 1.1905 s.
- T_P : orbital period; d_{ms} : satellite–Moon distance; R_1 : geometric term.
- Approximation of $R_1/d_{ms} \approx \cos(\alpha)$ is not used. R_1 is calculated directly. α after correction is used to fit $FWHM_x$.

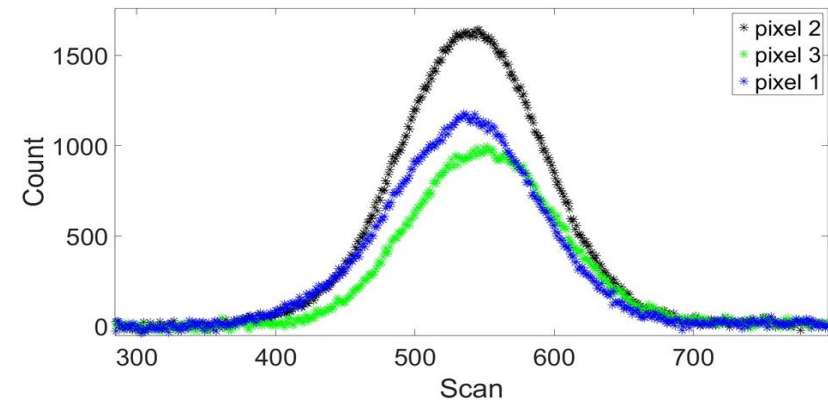


Along-Track FWHM Fitting Geometry

(a) 2-D Cold-Sky Scan



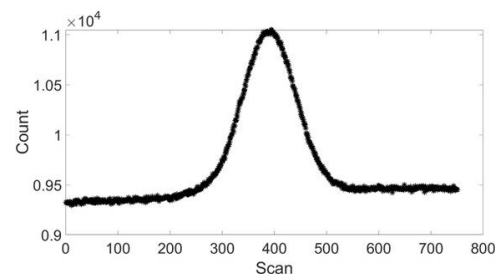
(b) Three Adjacent FOVs



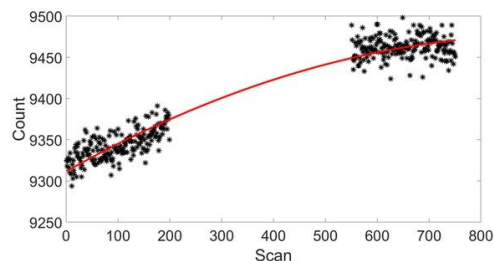
CH9: 2-D Scan and Adjacent-FOV Lunar Signals

FWHM Fitting Procedure

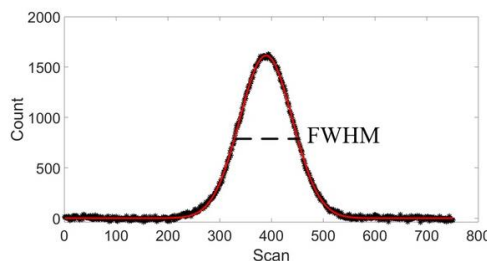
(a) CH9 Counts



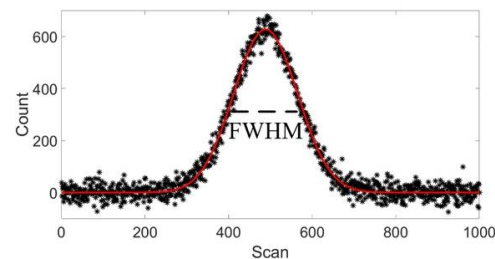
(b) Background Fit



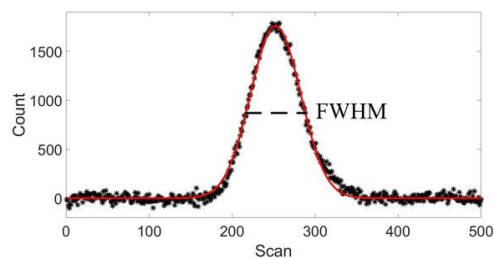
(c) CH9



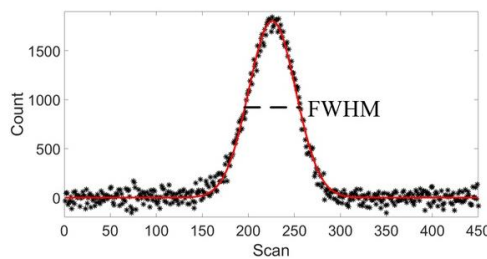
(d) CH4



(e) CH14



(f) CH16



Along-Track FWHM_x Fitting for the Four Channel Groups

- Determine the lunar peak scan and FOV from the two-dimensional cold-sky count array.
- Fit the local background on both sides of the peak window to obtain lunar excess counts.
- Fit a Gaussian function to the background-removed lunar signal; its center defines the lunar-signal center.
- Average the ± 3 scans around the center; multiply the half-maximum width in scans by 1.1905 s and convert the duration to FWHM_x.

FWHM Fits vs. Ground Measurements

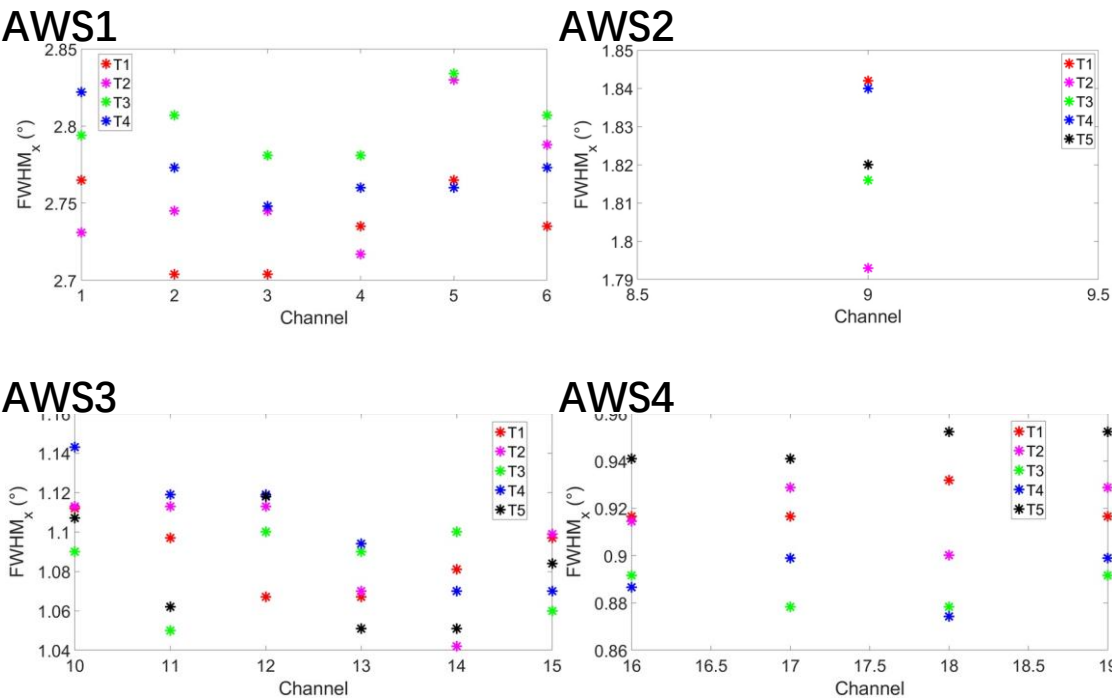


Fig. 7 FWHM_x from Lunar Observations T1–T5

- The fitted AWS1 FWHM_x: 2.704°–2.834°; range 0.130°; mean 2.767°; RMSE 0.036°.
- The fitted AWS2 FWHM_x: 1.793°–1.842°; range 0.049°; mean 1.822°; RMSE 0.018°.
- The fitted AWS3 FWHM_x: 1.042°–1.143°; range 0.101°; mean 1.088°; RMSE 0.025°.
- The fitted AWS4 FWHM_x: 0.874°–0.952°; range 0.078°; mean 0.912°; RMSE 0.024°.

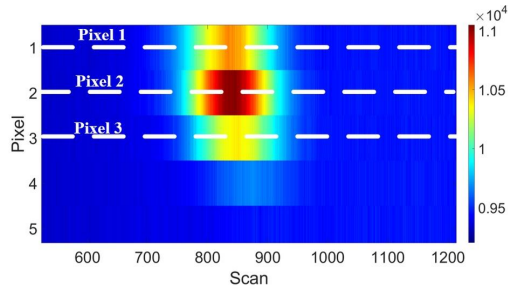
Channel	Channel Name	Center Frequency	FWHM(°)
1	AWS-11	50.3 GHz	FWHM _x =2.903; FWHM _y =3.533
2	AWS-12	52.8 GHz	
3	AWS-13	53.246 GHz	
4	AWS-14	53.596 GHz	
5	AWS-15	54.4 GHz	
6	AWS-16	54.94 GHz	FWHM _x =2.788; FWHM _y =3.438
7	AWS-17	55.5 GHz	
8	AWS-18	57.290344 GHz	
9	AWS-21	89 GHz	
10	AWS-31	165.5 GHz	
11	AWS-32	176.311 GHz	FWHM _x =0.859; FWHM _y =0.974
12	AWS-33	178.811 GHz	
13	AWS-34	180.311 GHz	
14	AWS-35	181.511 GHz	
15	AWS-36	182.311 GHz	
16	AWS-41	325.15±1.2 GHz	FWHM _x =0.917; FWHM _y =1.050
17	AWS-42	325.15±2.4 GHz	
18	AWS-43	325.15±4.1 GHz	
19	AWS-44	325.15±6.6 GHz	

Ground Reference: Albers et al., 2023

- The FWHM_x values for AWS1, AWS2, and AWS4 fall within the ground ranges. AWS3 is 0.1°–0.2° larger than the ground measurement.

Cross-Track FWHM & Pointing-Offset Inversion

(a) 2-D Scan



(b) Three FOVs

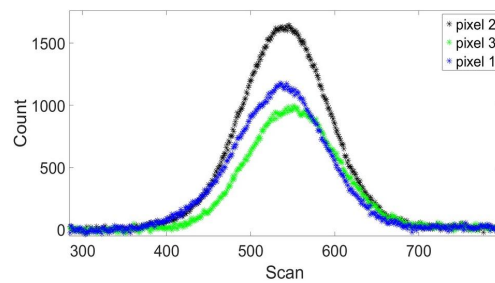
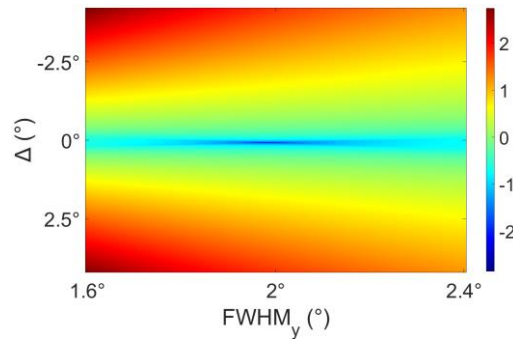


Fig. 3 CH9 Lunar Signal in Three FOVs

TA' and Gain

$$TA' = \frac{C_{c1} - C_{c2}}{G \cdot \eta}$$

$$G = \frac{C_w - C_{c2}}{T_w - T_c}$$



Loss function log10(fl) for CH9 T1 data

- Lunar signal also appears in adjacent FOVs; center = pixel 2.
- With FWHM_x fixed; search cross-track FWHM and pointing offset Δ .
- Ratio loss reduces sensitivity to simulated TA' amplitude.

Loss Function

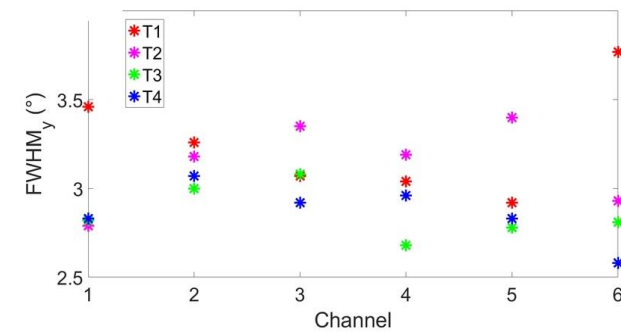
$$f_l = \left| \frac{TA'_{d,1}}{TA'_{d,2}} - \frac{TA'_{s,1}}{TA'_{s,2}} \right| + \left| \frac{TA'_{d,3}}{TA'_{d,2}} - \frac{TA'_{s,3}}{TA'_{s,2}} \right|$$

s: simulation; d: observation

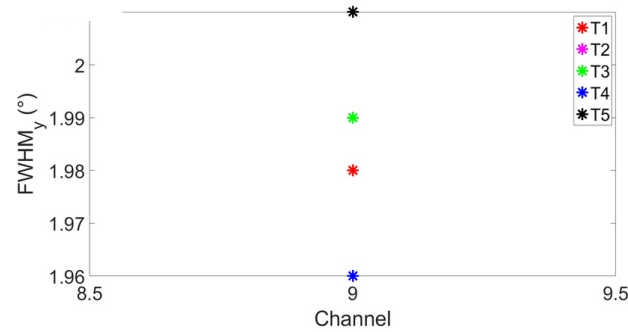
Search the Δ -cross-track FWHM plane; minimum loss gives cross-track FWHM and FOV-to-Moon-center pointing offset.

Cross-Track FWHM & Offset: Results

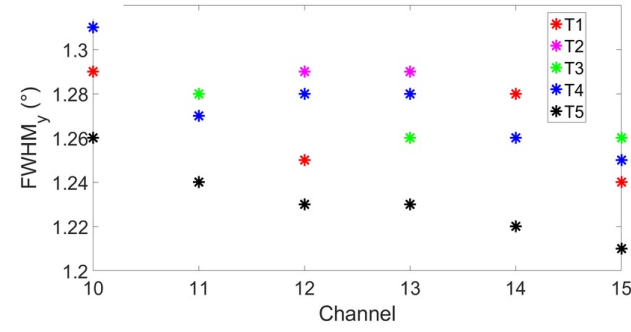
AWS1



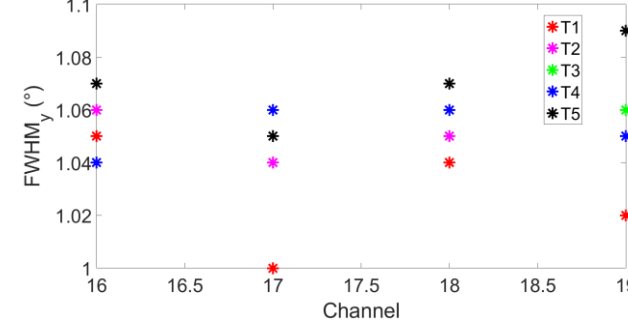
AWS2



AWS3



AWS4



Inverted cross-track FWHM and Δ

- The inverted AWS1 cross-track FWHM: 2.58°–3.77°; range 1.19°; mean 3.03°; RMSE 0.27°.
- The inverted AWS2 cross-track FWHM: 1.96°–2.01°; range 0.05°; mean 1.98°; RMSE 0.02°.
- The inverted AWS3 cross-track FWHM: 1.21°–1.32°; range 0.11°; mean 1.27°; RMSE 0.03°.
- The inverted AWS4 cross-track FWHM: 1.00°–1.09°; range 0.09°; mean 1.05°; RMSE 0.02°.

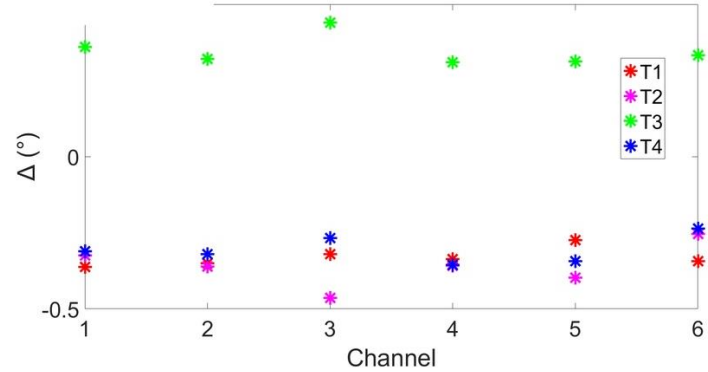
The FWHMy values for AWS1, AWS2, and AWS4 fall within the ground ranges. AWS3 is 0.1°–0.2° larger than the ground measurement.

Channel	Channel Name	Center Frequency	FWHM (°)	Cross-Track FWHM (°)
1	AWS-11	50.3 GHz	x:2.903, y:3.533	3.03
2	AWS-12	52.8 GHz	x:2.788, y:3.438	
3	AWS-13	53.246 GHz		
4	AWS-14	53.596 GHz		
5	AWS-15	54.4 GHz		
6	AWS-16	54.94 GHz		
7	AWS-17	55.5 GHz		
8	AWS-18	57.290344 GHz	x:2.712, y:3.323	
9	AWS-21	89 GHz	x:1.642, y:1.986	1.98
10	AWS-31	165.5 GHz	x:0.898, y:1.050	1.27
11	AWS-32	176.311 GHz	x:0.859, y:0.974	
12	AWS-33	178.811 GHz		
13	AWS-34	180.311 GHz		
14	AWS-35	181.511 GHz		
15	AWS-36	182.311 GHz		
16	AWS-41	325.15±1.2 GHz	x:0.917, y:1.050	1.05
17	AWS-42	325.15±2.4 GHz		
18	AWS-43	325.15±4.1 GHz		
19	AWS-44	325.15±6.6 GHz		

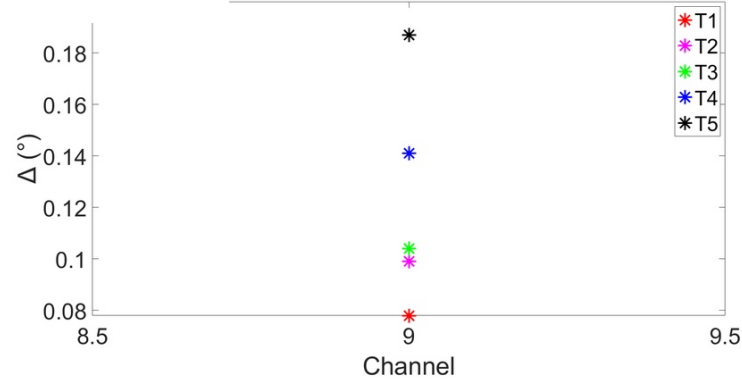
R. Albers, A. Emrich, and A. Murk, "Antenna Design for the Arctic Weather Satellite Microwave Sounder," IEEE Open Journal of Antennas and Propagation, vol. 4, pp. 686–694, 2023, doi: 10.1109/ojap.2023.3295390.

Pointing-offset between Moon center and FOV

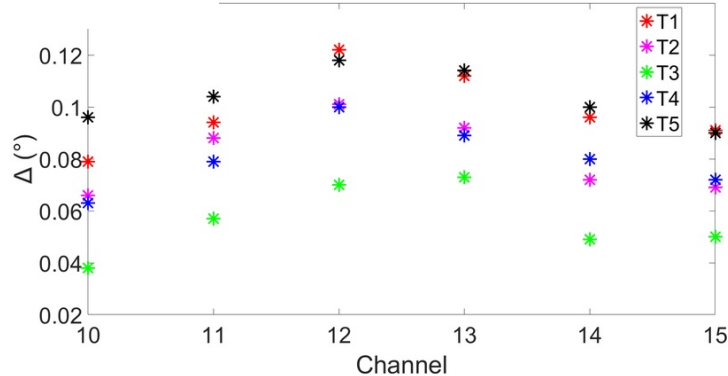
AWS1



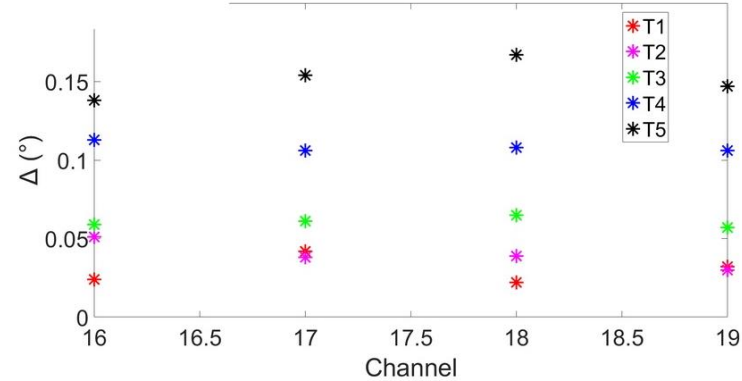
AWS2



AWS3



AWS4

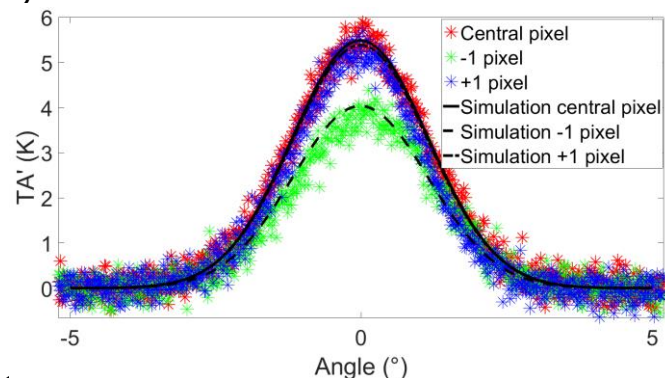


Within each group and date, pointing offsets are nearly identical. The inversion result is consistent with the factor that channels in the same group share one feed horn.

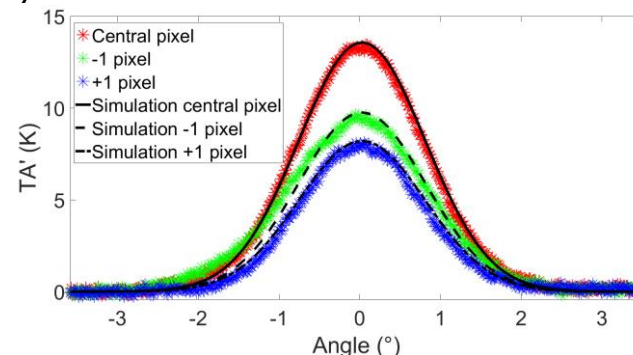
For AWS1, mean Δ at T1–T4 is -0.331° , -0.360° , 0.346° , and -0.306° ; maximum channel differences in Δ are 0.087° , 0.210° , 0.130° , and 0.120° . Group-to-group Δ differences reflect the four feed-horn pointing directions.

Validation of FWHM and Pointing Offset with Three Adjacent Pixels

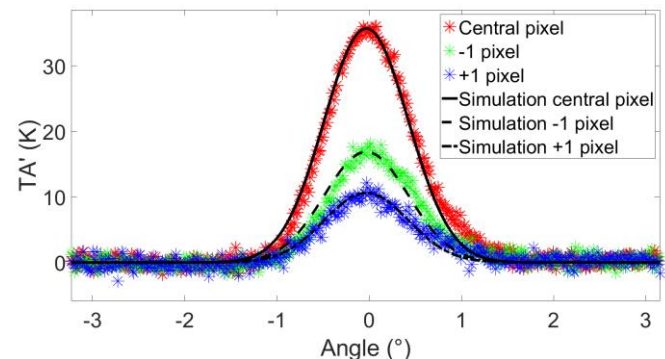
CH4, 54 GHz



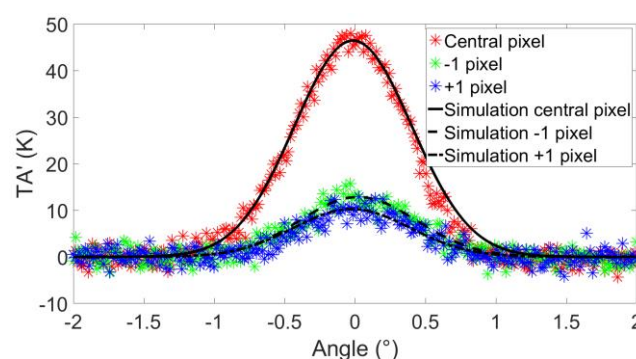
CH9, 89 GHz



CH14, 183 GHz



CH16, 325 GHz



- CH4: $\text{FWHM}_x = 2.73^\circ$, cross-track $\text{FWHM} = 3.20^\circ$, $\Delta = -0.337^\circ$.
- CH9: $\text{FWHM}_x = 1.82^\circ$, cross-track $\text{FWHM} = 1.99^\circ$, $\Delta = 0.078^\circ$.
- CH14: $\text{FWHM}_x = 1.03^\circ$, cross-track $\text{FWHM} = 1.26^\circ$, $\Delta = 0.096^\circ$.
- CH16: $\text{FWHM}_x = 0.93^\circ$, cross-track $\text{FWHM} = 1.05^\circ$, $\Delta = 0.024^\circ$.
- Simulations reproduce the central/ ± 1 -pixel TA' pattern.

FWHM/ Δ : Three-Pixel TA'

- For CH4, the central-pixel TA' is close to the +1-pixel TA' . The difference is below 0.5 K, and both exceed the -1-pixel TA' by more than 1.5 K, indicating that the Moon lies between the central and +1-pixel FOVs.
- For CH9 (89 GHz), the central-pixel peak TA' is about 4 K and 5 K larger than the -1- and +1-pixel values, which means the Moon center is very close to the central pixel. Simulated and measured peaks differ by less than 0.5 K.
- For CH14 (183 GHz), the corresponding differences are about 19 K and 25 K.
- For CH16 (325 GHz), they are about 34 K and 37 K. The simulations agree with the measurements.

Multi-Channel TA'

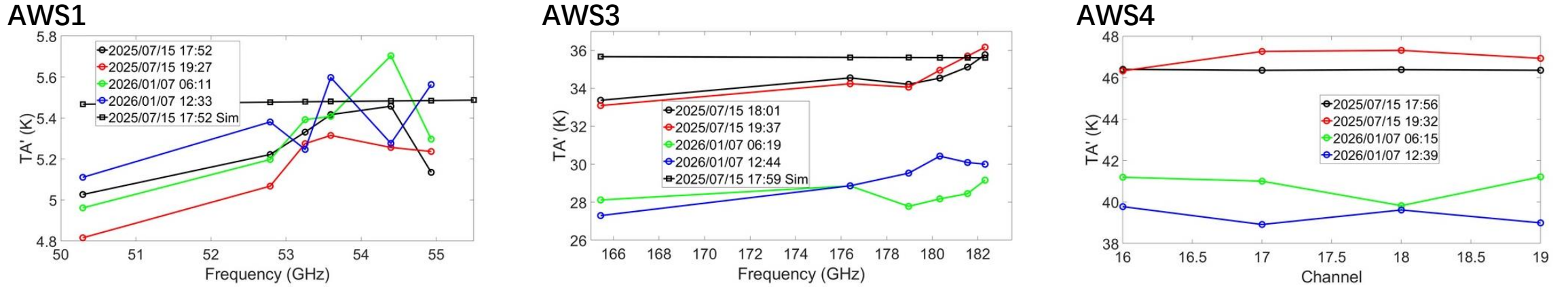


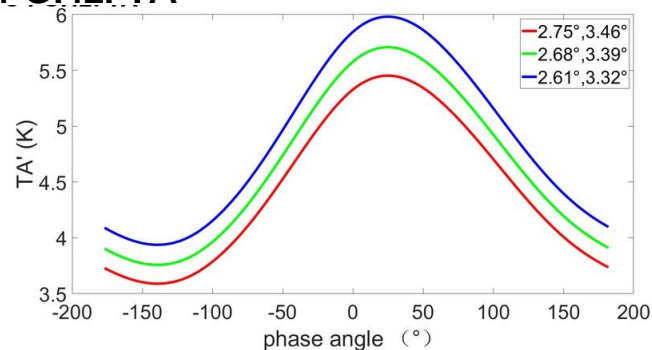
Fig. 11 Observed and Simulated Multi-Channel Lunar TA' for AWS1, AWS3, and AWS4

- Maximum within-group TA' differences reach 13%, 10%, and 3% for AWS1, AWS3, and AWS4 data.
- Channels in a group share one feed horn and pointing direction; simulations show negligible TA' differences from the small frequency differences.
- Measured TA' shows systematic patterns: AWS1 and AWS3 TA' generally increases by channel, and AWS4 TA' varies least.
- No corresponding pattern appears in Earth-view data. The lunar differences are therefore more likely associated with small inter-channel FWHM differences caused by differences in center frequency.

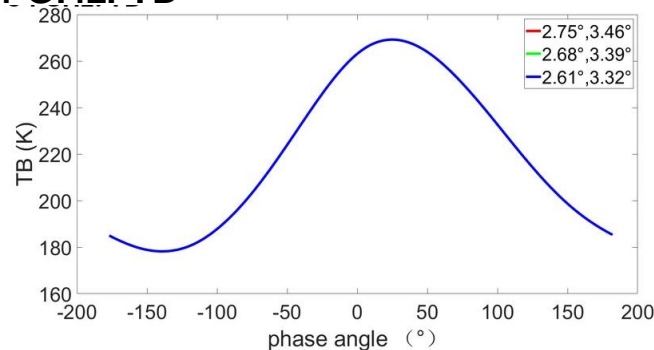
Simulated TA' and TB for Different FWHMs

One variable that is insensitive to FWHM is needed for inter-channel assessment.

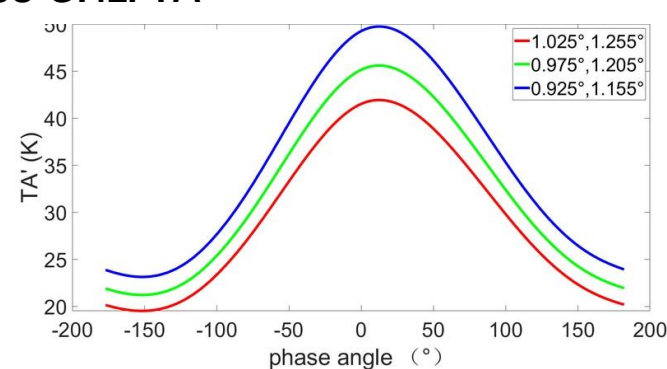
54 GHz: TA'



54 GHz: TB



183 GHz: TA'



183 GHz: TB

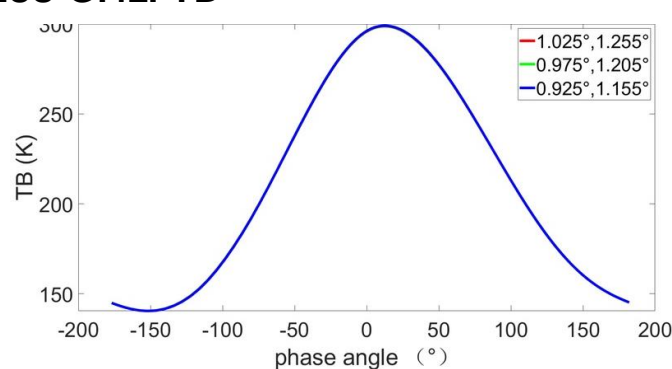


Fig. 12 Simulated TA' and Disk-Integrated TB for Different FWHMs

- As FWHM increases, the wider beam dilutes lunar radiation and the TA' peak decreases markedly.

- At 54 GHz, each 0.07° FWHM increase reduces the TA' peak by about 4.5% and 4.6%.

- At 183 GHz, each 0.05° FWHM increase reduces the TA' peak by about 8.3% and 8.1%.

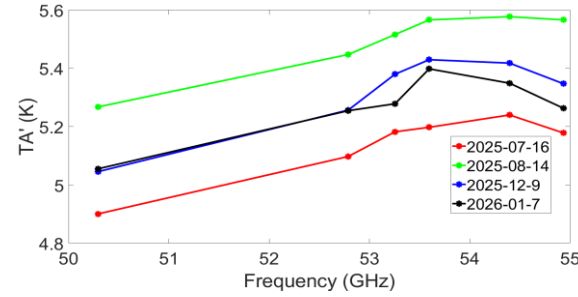
- Disk-integrated TB differs by less than 1‰ and is better suited to relative comparison within a channel group.

TB Inversion

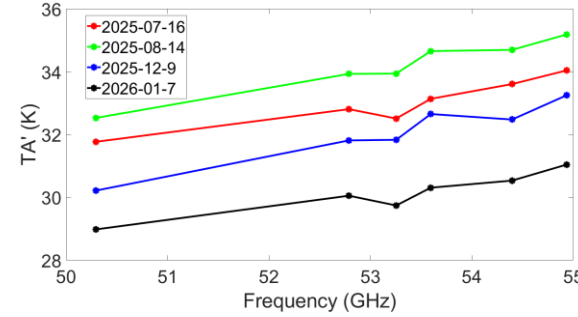
Before calculating the disk-integrated TB, the random variability should be reduced.

Mean TA' of about 10 observations within one day, which have similar phase angles, can reduce random variability.

AWS1



AWS3



AWS4

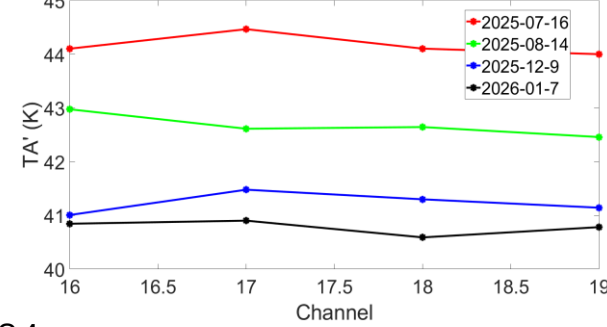


Fig. 13 Mean TA' : AWS1, AWS3, and AWS4

- For AWS1, mean TA' increases from CH1 to CH5 and decreases at CH6. The four-date maximum–minimum differences are 6.5%, 5.6%, 7.1%, and 6.4%.
- For AWS3, mean TA' rises from CH10 to CH11, drops at CH12, then increases gradually. The differences are 6.7%, 7.5%, 9.1%, and 6.6%.
- AWS4 has the smallest inter-channel variation: 1.0%, 1.2%, 1.1%, and 0.8%.

TB Inversion steps:

- obtain mean Δ_m ;
- normalize TA' to $\Delta=0^\circ$;
- average same-day observations;
- search $FWHM_x$ and $FWHM_y$ to match simulated TA' with observed TA' to invert the FWHM of each channel accurately.
- With the accurate FWHM, we calculate TBs of each channel.

$$T_B = \frac{TA'}{F} \quad F = \sum_i G_i \cdot M_i$$

Normalize:

$$TA'_{Ni} = TA'_i \frac{TA'_s(0^\circ)}{TA'_s(\Delta_m)}$$

TB Inversion

- (1) For each event, average multi-channel Δ is used to obtain Δ_m ; remove the effect of Δ from TA' and normalize at $\Delta=0^\circ$ to obtain TA'_n
- (2) Average same-day TA'_n for each channel to suppress noise; use the mean TA'_n and satellite–Moon distance in the inversion.
- (3) Search $FWHM_x$ and cross-track FWHM within $\pm 0.3^\circ$ of the fitted $FWHM_x$ and inverted $FWHM_y$ with searching step of 0.01° . For each $FWHM_x$ / $FWHM_y$ pair, simulate TA' .
- (4) When simulated TA' matches observed TA' , select the corresponding $FWHM_x$ and $FWHM_y$.
- (5) With inverted FWHM and $\Delta=0^\circ$, calculate disk-integrated lunar TB and r_{TB} .

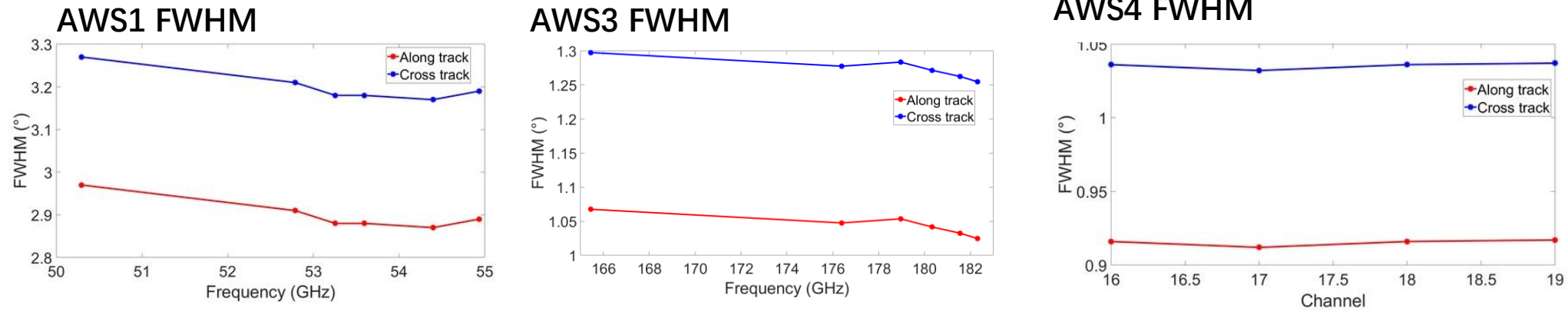
TB Calculation (Burgdorf 2019):

$$T_B = \frac{TA'}{F} \quad F = \sum_i G_i \cdot M_i$$

Relative Ratio:

$$r_{TB} = \frac{TB_{ch}}{\max(TB_{ch})}$$

FWHM Inversion

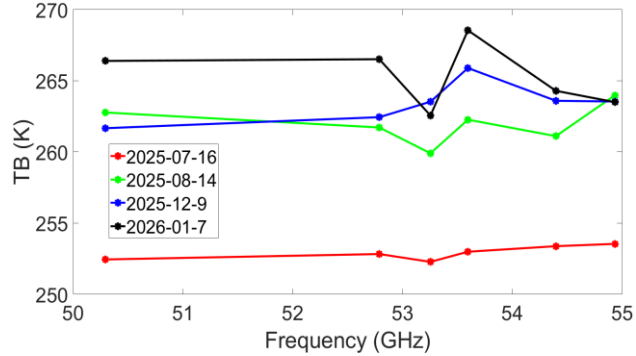


The inverted FWHM with the data from 07-16 2025

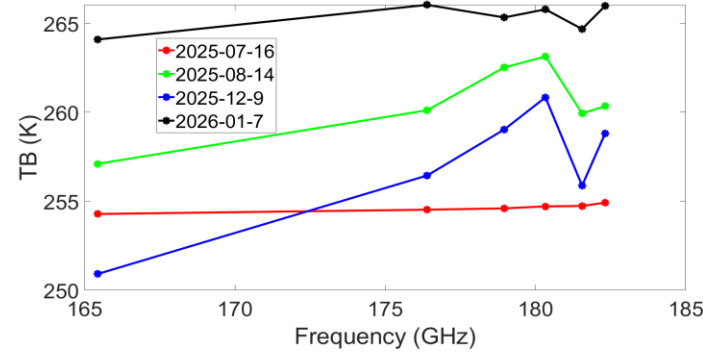
- FWHMs decrease when the frequency increases for AWS1 and AWS3. FWHMs of AWS4 do not show significant changes because the central frequencies are not changed.
- The inverted FWHM is directly related to observed TA' . A larger observed TA' yields a smaller FWHM estimate. For AWS1 CH1–CH6, the along-track FWHM_x values are 2.97°, 2.91°, 2.88°, 2.88°, 2.87°, and 2.89°. The cross-track FWHM values are 3.27°, 3.21°, 3.18°, 3.18°, 3.17°, and 3.19°. These results fall within the previously derived FWHM range and the ground-measurement FWHM range.
- For AWS3 CH10–CH15, the along-track FWHM_x values are 1.07°, 1.05°, 1.05°, 1.04°, 1.03°, and 1.02°. The cross-track FWHM values are 1.30°, 1.28°, 1.28°, 1.27°, 1.26°, and 1.25°.
- For AWS4 CH16–CH19, the along-track FWHM_x values are 0.92°, 0.91°, 0.92°, and 0.92°. The cross-track FWHM values are 1.04°, 1.03°, 1.04°, and 1.04°.

TB Inversion Results

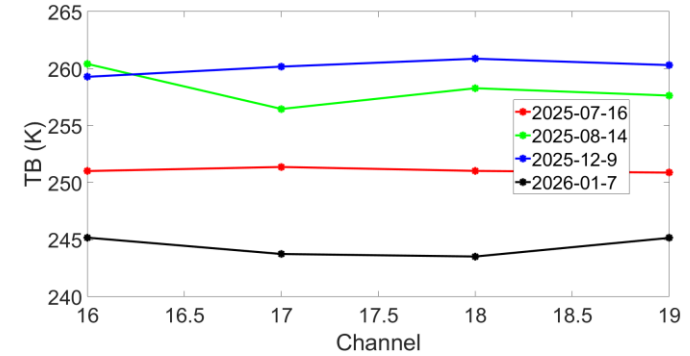
AWS1 TB



AWS3 TB



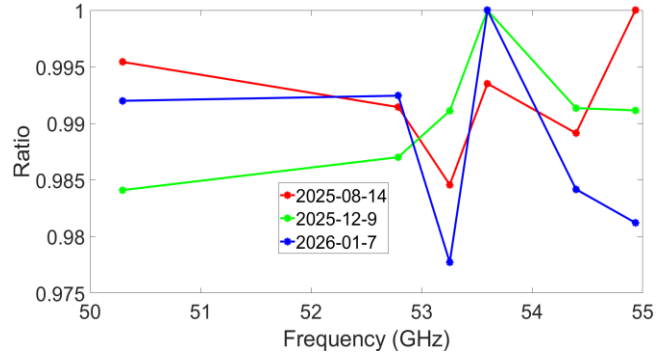
AWS4 TB



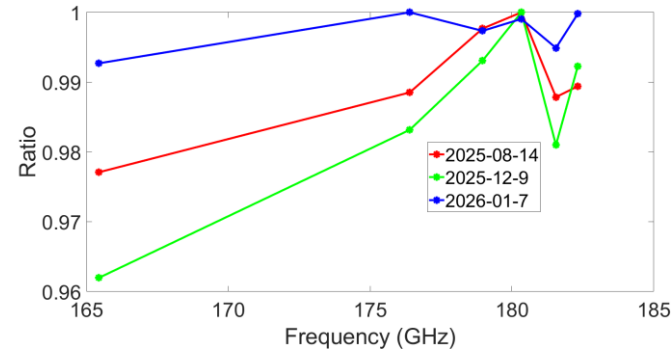
- For AWS1, the maximum inter-channel TB differences on August 14 and December 3, 2025, and January 7, 2026, are 4.1 K, 4.2 K, and 6 K. The FWHM inverted from observations near July 16, 2025, effectively removes the tendency of TA' to increase with channel number.
- For AWS3, the maximum inter-channel TB differences are 6.0 K, 10.0 K, and 1.9 K. The FWHM inverted near July 16, 2025, removes the increasing TA' trend on January 7, 2026, but not those on August 14 and December 9, 2025.
- For AWS4, the maximum inter-channel TB differences are 3.9 K, 1.6 K, and 1.7 K.

TB Inversion Results

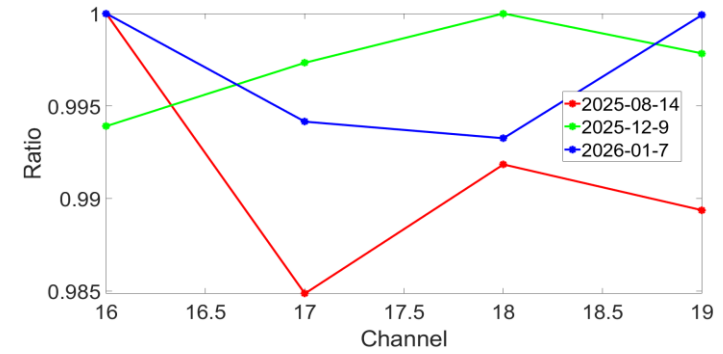
AWS1 r_{TB}



AWS3 r_{TB}



AWS4 r_{TB}



- For AWS1, the mean normalized TB ratios on August 14 and December 3, 2025, and January 7, 2026, are 0.995, 0.991, and 0.988. These differences are smaller than those among channel TA' values.
- For AWS3, the mean normalized TB ratios are 0.990, 0.986, and 0.997. These differences are smaller than those among channel TA' values.
- For AWS4, the mean normalized TB ratios are 0.992, 0.997, and 0.996. AWS4 has the smallest relative inter-channel differences and the highest within-group consistency.

Relative Ratio:

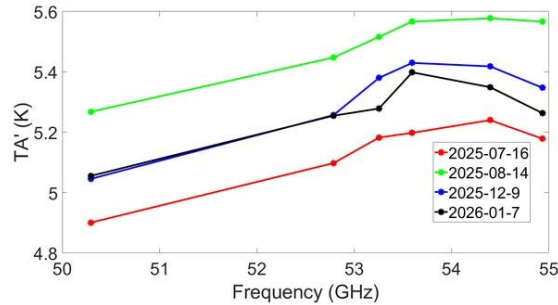
$$r_{TB} = \frac{TB_{ch}}{\max(TB_{ch})}$$

Inter-Channel Normalization

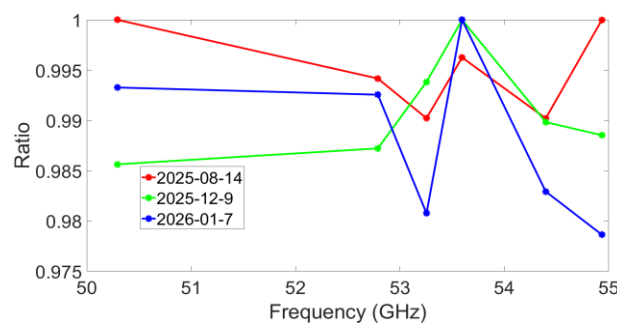
Another method to remove the effect of changes in FWHM between channels: Dividing the each channel's TA' by the reference-date TA' to obtain the per-channel ratio rp . Then, dividing the rp by the max rp in the same group.

$$r = \frac{rp_{ch}}{\max(rp)}$$

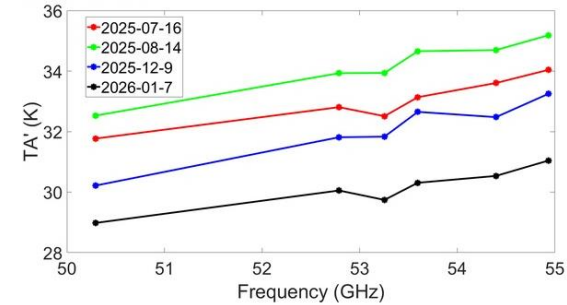
AWS1 TA'



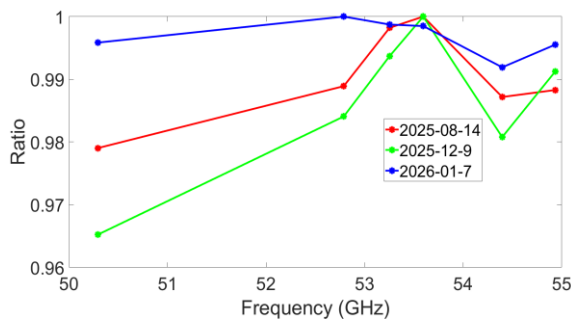
AWS1 Ratio



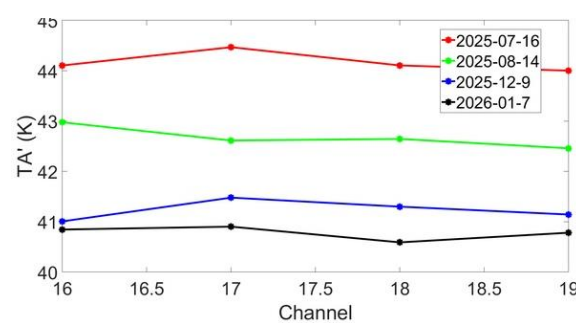
AWS3 TA'



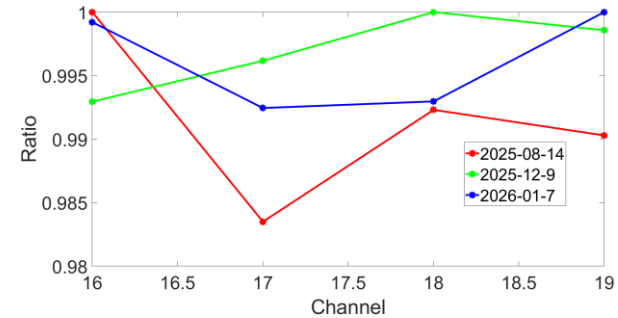
AWS3 Ratio



AWS4 TA'

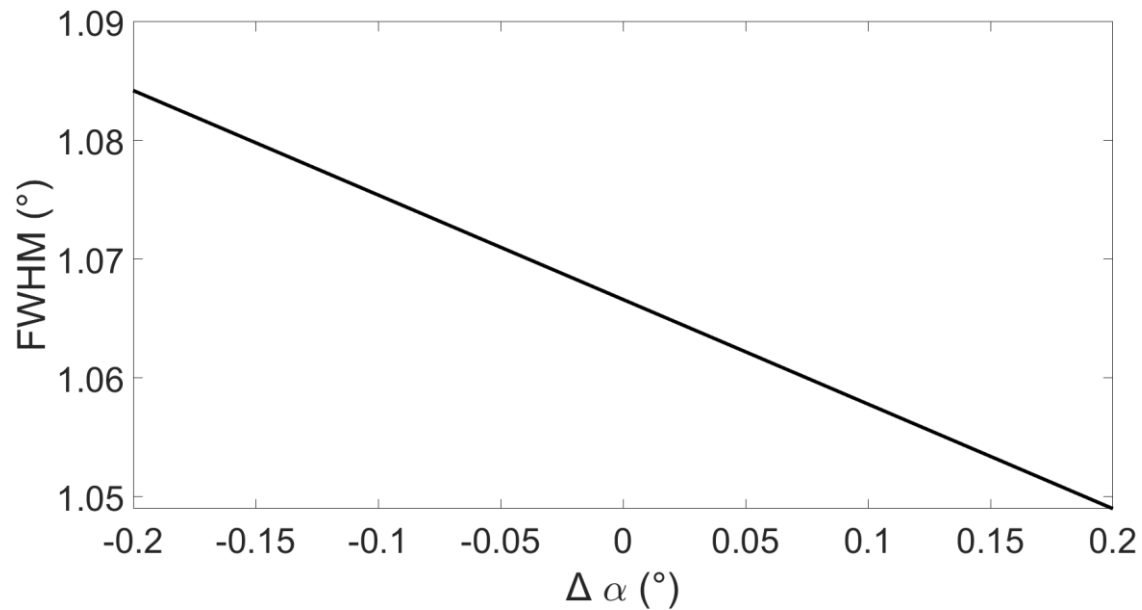


AWS4 Ratio

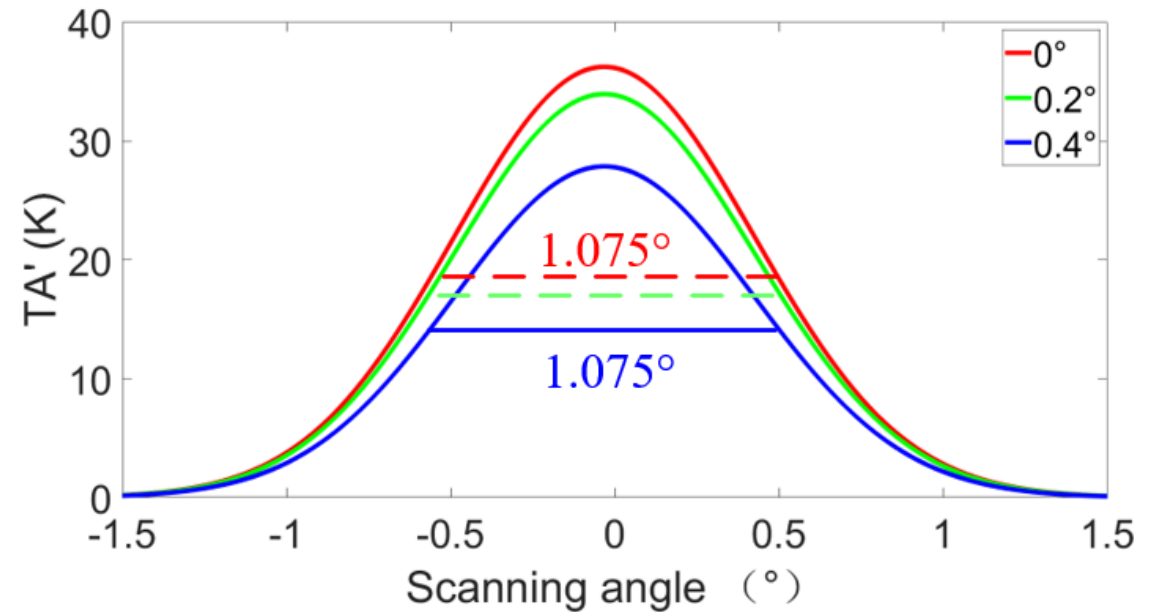


Only 1–2 r values for AWS1/AWS3 are below 0.98. Three-date mean r : AWS1 = 0.995, 0.991, 0.988; r : AWS3 = 0.990, 0.986, 0.997. For AWS4, one value is below 0.99; mean r : 0.992, 0.997, 0.996. r nearer 1 indicates better consistency.

Error Analysis



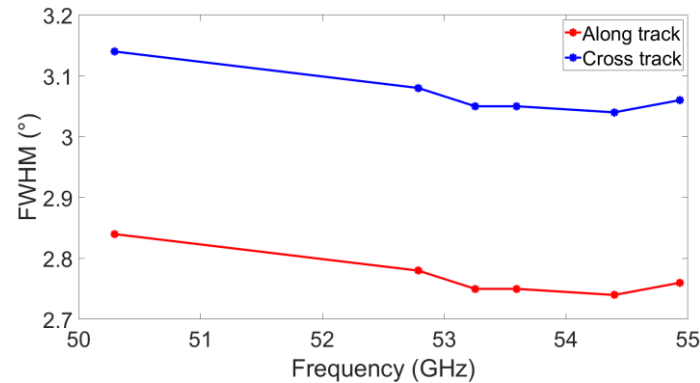
FWHM_x Sensitivity to $\Delta \alpha$



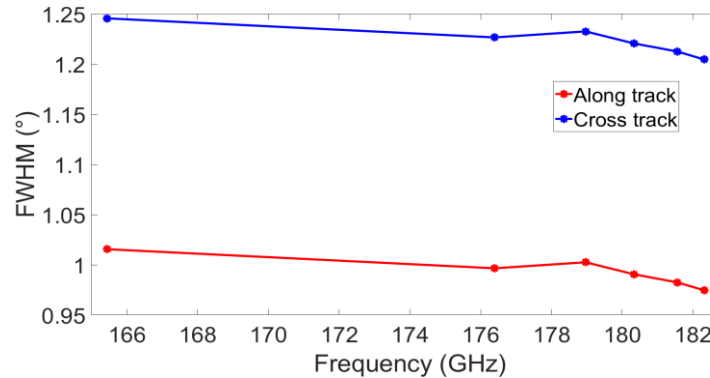
Different Δ : Simulated TA'

- Influence of $\Delta \alpha$ and Δ are shown above.
- For velocity-direction pointing offsets below 3°, the effect on fitted FWHM is less than 3%.
- The effect of the elliptical orbit on fitted FWHM can be neglected.
- The FOV-to-Moon offset Δ changes adjacent-pixel TA' ratios and is an important error source in cross-track FWHM inversion.

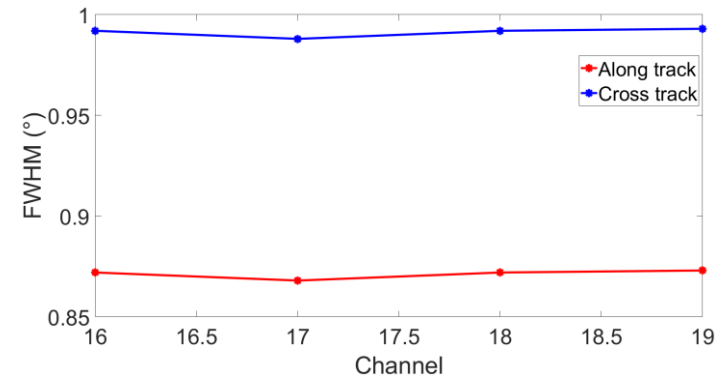
Effects of Lunar Microwave Model Parameters



AWS1



AWS3



AWS4

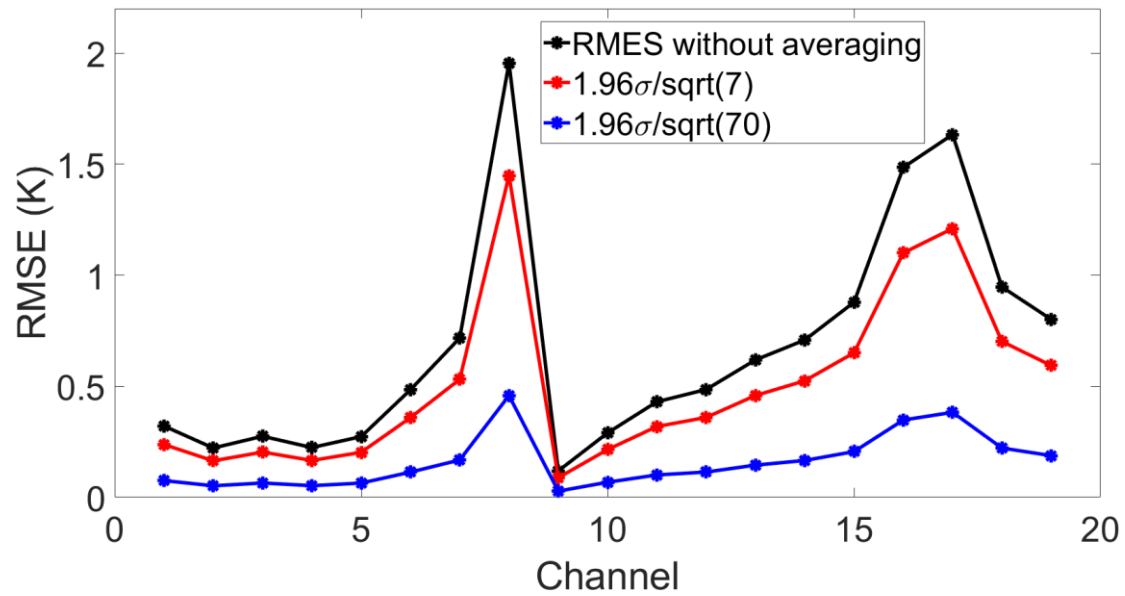
FWHM Inverted with Fresnel Emissivity

- For AWS1 CH1–CH6, the inverted along-track FWHM_x values are 2.84°, 2.78°, 2.75°, 2.75°, 2.74°, and 2.76°. The cross-track FWHM values are 3.14°, 3.08°, 3.05°, 3.05°, 3.04°, and 3.06°. **The inverted FWHM values are about 0.13°, or 4%, below the FWHM values from the E=0.979 simulation.** Fresnel emissivity produces lower simulated TB. A smaller FWHM increases TA' , so a lower model TB leads to a smaller inverted FWHM.
- For AWS3 CH10–CH15, the inverted along-track FWHM_x values are 1.02°, 1.00°, 1.00°, 0.99°, 0.98°, and 0.97°. The cross-track FWHM values are 1.25°, 1.23°, 1.23°, 1.22°, 1.21°, and 1.20°. **The inverted FWHM values are about 0.05°, or 4.5%, below the FWHM values from the E=0.979 simulation.**
- For AWS4 CH16–CH19, the inverted along-track FWHM_x values are about 0.87°, with inter-channel differences below 0.005°. The cross-track FWHM values are about 0.99°, also with differences below 0.005°. **The inverted FWHM values are about 0.05°, or 5%, below the FWHM values from the E=0.979 simulation.**
- Within a channel group, FWHM difference between channels do not change with lunar model.

Error Analysis

Averaging repeated TA' observations suppresses random variability. If TA' is the mean of n samples, its 95% confidence interval is:

$$\left[\mu - 1.96 \frac{\sigma}{\sqrt{n}}, \mu + 1.96 \frac{\sigma}{\sqrt{n}} \right]$$



Moon-Free Cold-Sky TA RMSE

- The RMSEs are consistent with the ground measurements.
- n is the number of observations. For a single observation, seven adjacent counts are averaged. With $n=7$, the TA' sample mean lies within $[-0.74\sigma, 0.74\sigma]$ at the 95% confidence level.
- Repeated observations are also averaged for each channel to further suppress random variability. The effective sample size is $n=70$ for ten observations, and the TA' sample mean lies within $[-0.23\sigma, 0.23\sigma]$ at the 95% confidence level.

Conclusion

- AWS lunar observations can assess on-orbit MWR pointing, along-track FWHM_x, cross-track FWHM, and FOV-to-Moon offset Δ .
- α corrections align simulated lunar-observation times with measured peak times and bring the fitted FWHM_x closer to ground measurements.
- FWHMs for AWS1, AWS2, and AWS4 generally agree with ground measurements; AWS3 values are larger by 0.1-0.2° than the ground measurement.
- Simulated TA' is nearly identical within a group, whereas measured TA' shows clear inter-channel differences. Channel-specific FWHM and disk-integrated TB support relative inter-channel assessment.
- Direct TA' normalization indicates the best inter-channel consistency for AWS4, with a mean maximum difference of about 0.8% over three dates.

The work in progress

- Dezhang is processing NOAA-20 data to validate and improve this method.

Questions

1. What is the impact of minor FWHM differences across channels on Earth observation and related applications ?
2. Are the FWHM and antenna efficiency constant over different dates ?
3. How to validate the change of FWHM and antenna efficiency with time ?