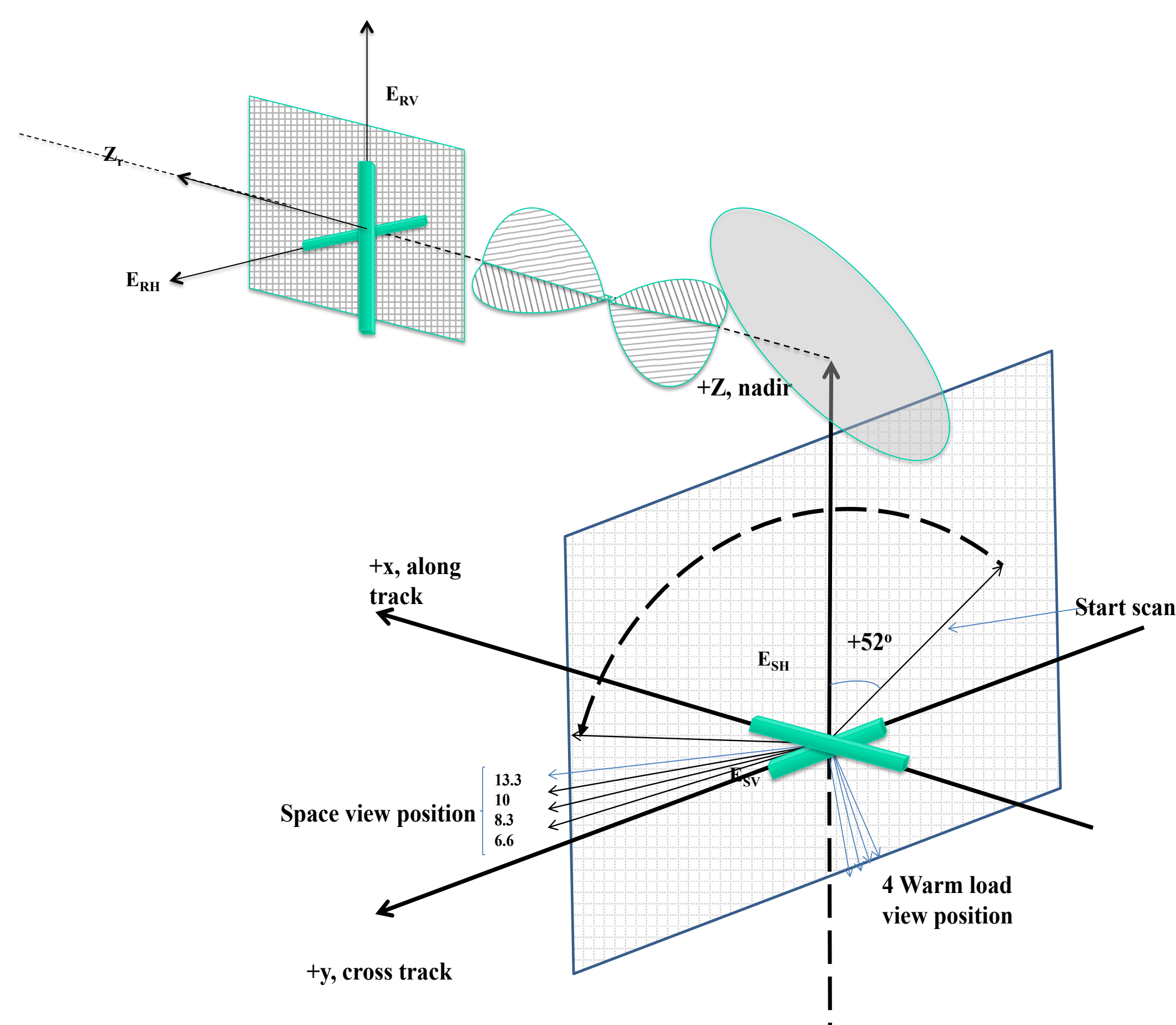


Abstract: The Advanced Technology Microwave Sounder (ATMS) onboard the Suomi National Polar-orbiting Partnership (NPP) satellite is a total power radiometer and scans across the track within a range of $\pm 52.77^\circ$ from nadir. It has 22 channels and measures the microwave radiation at either quasi-vertical or quasi-horizontal polarization from the Earth's atmosphere. ATMS scanning reflector is made of the beryllium coated with gold and can have an emission due to the surface roughness. An estimate of the reflector emissivity in the prelaunch phase was not explored. In this study, a new methodology is developed to assess the antenna emission from the ATMS pitch-over observations. It is found that the antenna emission is significant and dominates the scan angle dependent features in the ATMS antenna temperatures. Retrieved emissivity from K to G bands ranges from 0.002 to 0.006. Error model was also developed to assess the impact of antenna emissivity to calibration accuracy of antenna temperature products. Simulation results show that the calibration error are scene temperature dependent and can be as large as 2.5K for space view.

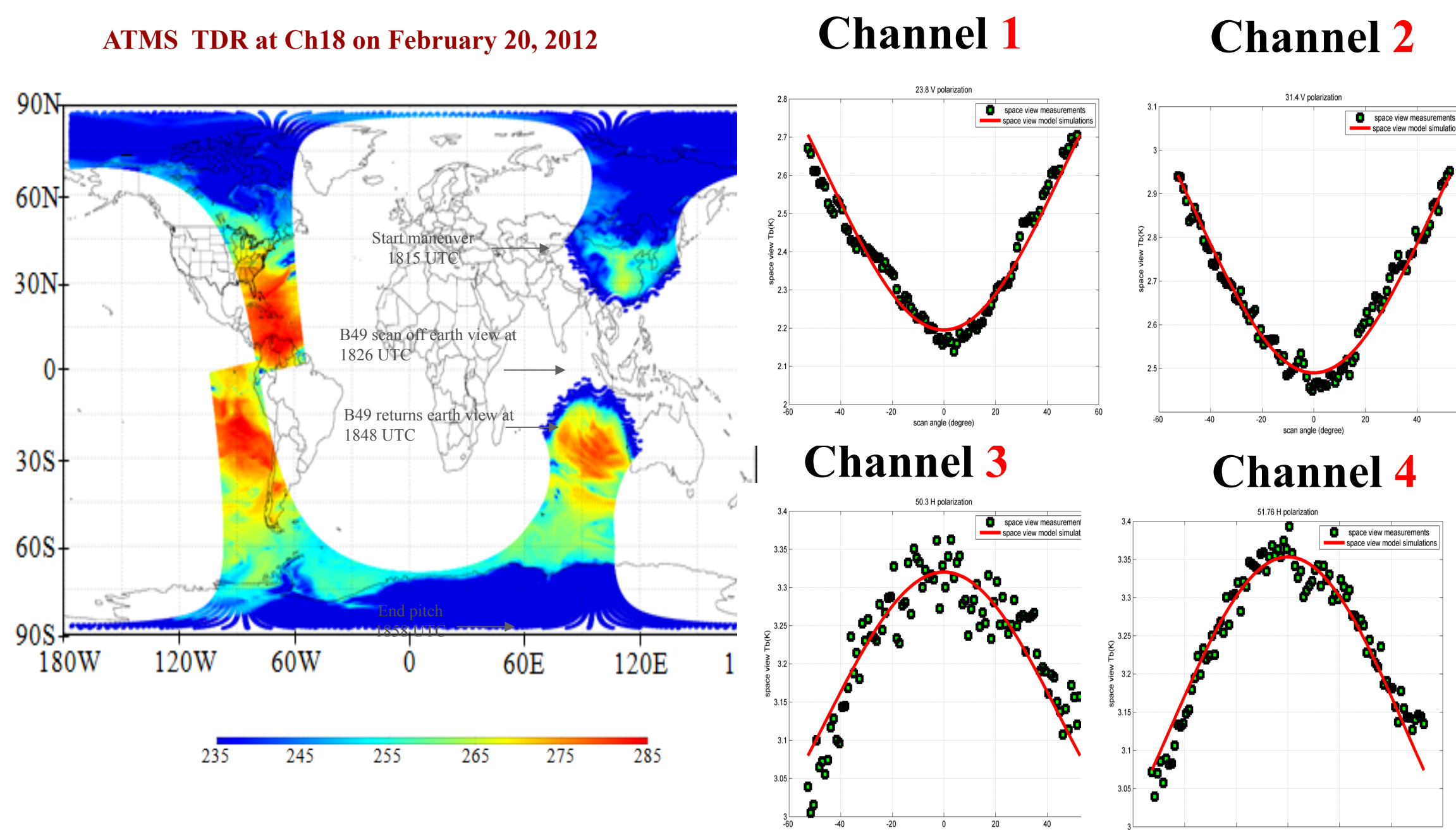
Antenna Reflection and Transmission Model

ATMS antennas consist of a plane reflector mounted on a scan axis at a 45° tilt angle so that radiation is reflected from a direction perpendicular to the scan axis into a direction along the scan axis (i.e., a 90° reflection). With the scan axis oriented in the along-track direction, this results in a cross-track scan pattern. The reflected radiation is focused by a stationary parabolic reflector onto a dichroic plate (polarizing grid), and then either reflected to or passed through to a feedhorn. Each aperture/reflector serves two frequency bands for a total of four bands. It is speculated that the rotating plane reflector has its own emission due to the coating material used.



ATMS Antenna Reflection Model for Pitch-over Observations

On February 20, 2012, ATMS on the Suomi NPP satellite was commanded to pitch over, scan the deep space and collect the 18-minutes of data with 96 of field of views (FOVs) along each scan. In principle, the brightness temperatures after calibration from the cold space should be uniform across the scan. It has been found that the pitch maneuver data showed a scan-angle dependent radiometric bias with respect to the cold space background brightness temperature of 2.73 K. In particular, the biases at ATMS channels 1,2, and 16 are a sine-squared function of scan angle (smile shape) whereas the rest of channels are a cosine-squared function of scan angle (frown shape).



Using the Mueller matrix of reflection and transmission at 45° angle for a bulk-material reflector, we derived a full vector expression for reflected radiation for non-lossless, polarized rotating reflector.

$$\begin{bmatrix} R_{Qv} \\ R_{Qh} \\ R_{Q3} \\ R_{Q4} \end{bmatrix} = \begin{bmatrix} R_s + e_h(R_{rfl} - R_s) + [(R_{rfl} - R_s)(e_v - e_h)]\sin^2\theta \\ R_s + e_h(R_{rfl} - R_s) + [(R_{rfl} - R_s)(e_v - e_h)]\cos^2\theta \\ (R_{rfl} - R_s) \cdot e_h \cdot (1 - e_h) \cdot \sin 2\theta \\ 0 \end{bmatrix}$$

In equation above, $R_s = R_c$ when reflector scans cold space and $R_s = R_w$ when it scans to calibration blackbody target. It provides a physical model for simulating pitch over observations obtained through a polarized antenna reflector. When a non-lossless plane reflector is used to scan the scene, a uniform unpolarized radiation can be changed to polarized and expressed as a function of antenna reflectivity, reflector physical temperature, scene temperature, and scan angle.

Reflector Emissivity Spectrum

In normal observations, ATMS continually scans the Earth scene, cold space and warm load calibration target. During the pitch-over maneuver, the unpolarized cold-space is scan in 96 scan angles. Given θ_s , θ_c , and θ_w are the scan angle for 'earth scene', cold space and warm load respectively, the incident radiation from "earth scene" is:

$$R_{Qv}^s = R_{rfl} + r_h(R_c - R_{rfl}) + [(R_c - R_{rfl})(r_h^2 - r_h)]\sin^2\theta_s$$

$$R_{Qh}^s = R_{rfl} + r_h(R_c - R_{rfl}) + [(R_c - R_{rfl})(r_h^2 - r_h)]\cos^2\theta_s$$

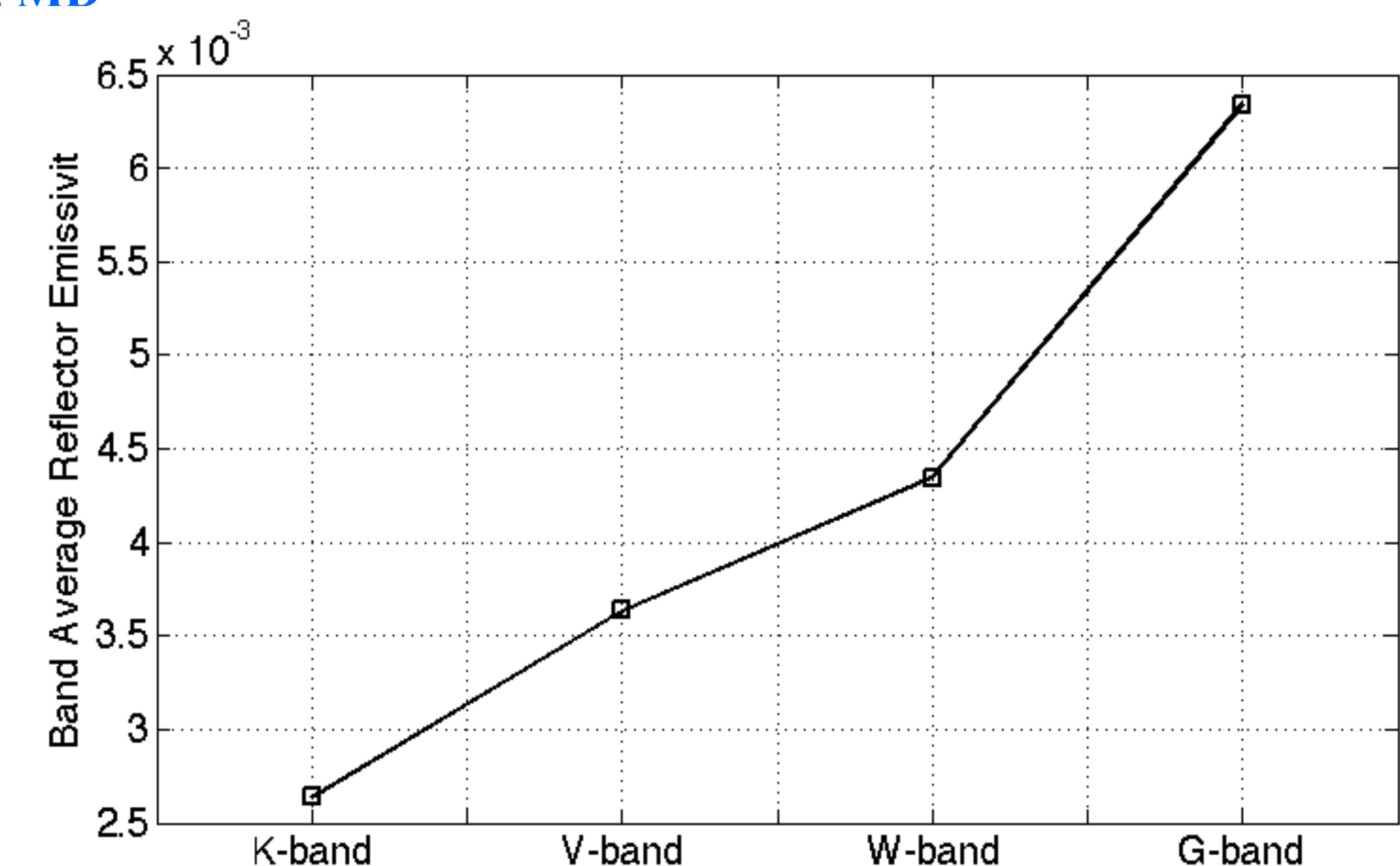
In equation above, superscript s represents observation target, it can be scene, cold space and warm target. By applying the two-point calibration equation, the antenna emissivity for Quasi-V channels can be solved as:

$$\varepsilon_h = \frac{\delta(R_w - R_c)}{\delta[(R_w - R_{rfl})\sin^2\theta_w - (R_c - R_{rfl})\sin^2\theta_c] - (R_c - R_{rfl})(\sin^2\theta_s - \sin^2\theta_c)}$$

Assuming C_s , C_c , and C_w are the corresponding receiver output counts for scene, cold space and warm load respectively, $\delta = \frac{C_s - C_c}{C_w - C_c}$

for Quasi-H channels, the antenna emissivity should be calculated as

$$\varepsilon_v = 1 - (1 - \varepsilon_h)^2$$



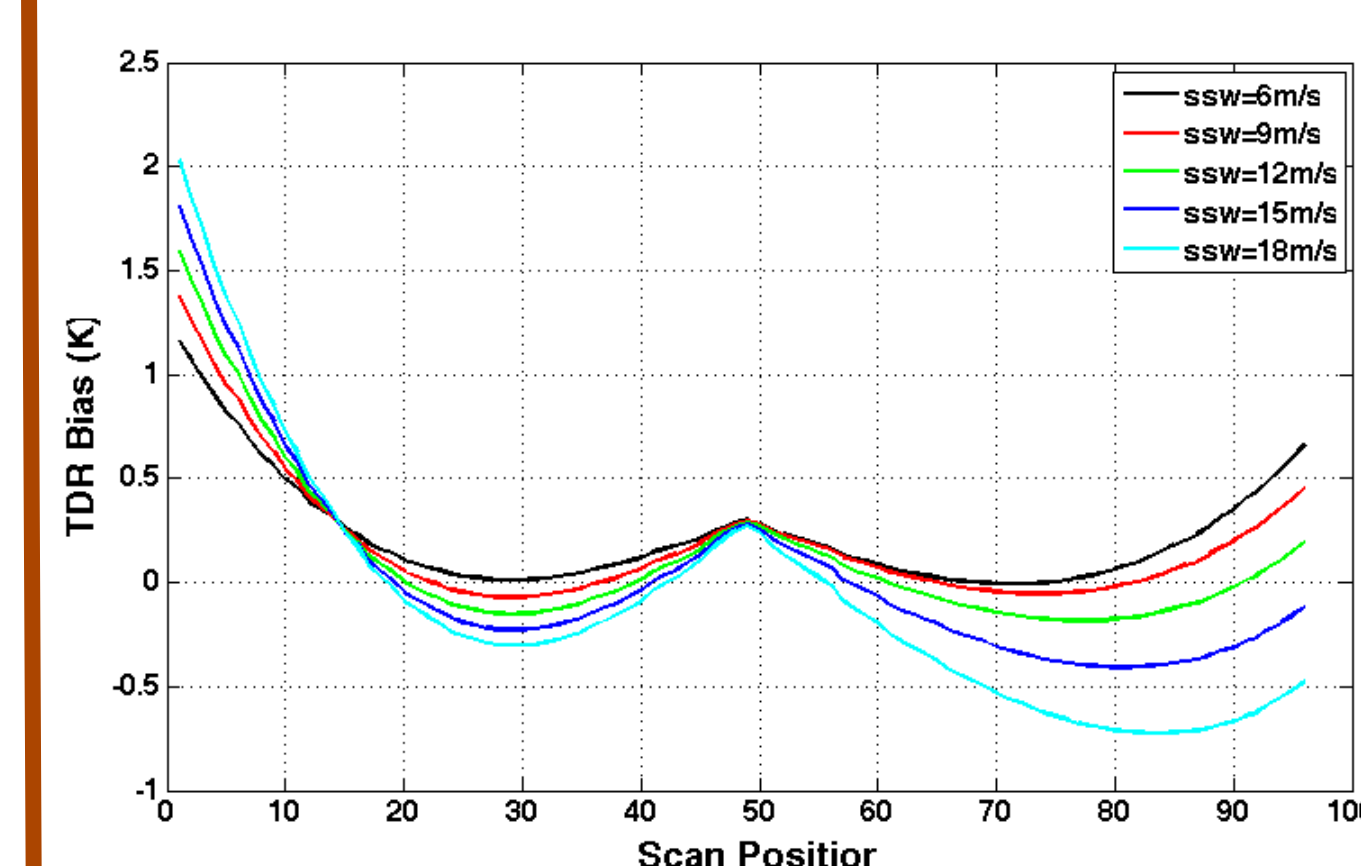
Impact of Reflector Emission on Polarized Antenna Temperature

For polarized scene, the impact of reflector emission is dependent on the temperature difference between antenna reflector and V-pol scene, the scan angle dependent feature in the error is mainly dominated by the third Stokes component of the scene radiation.

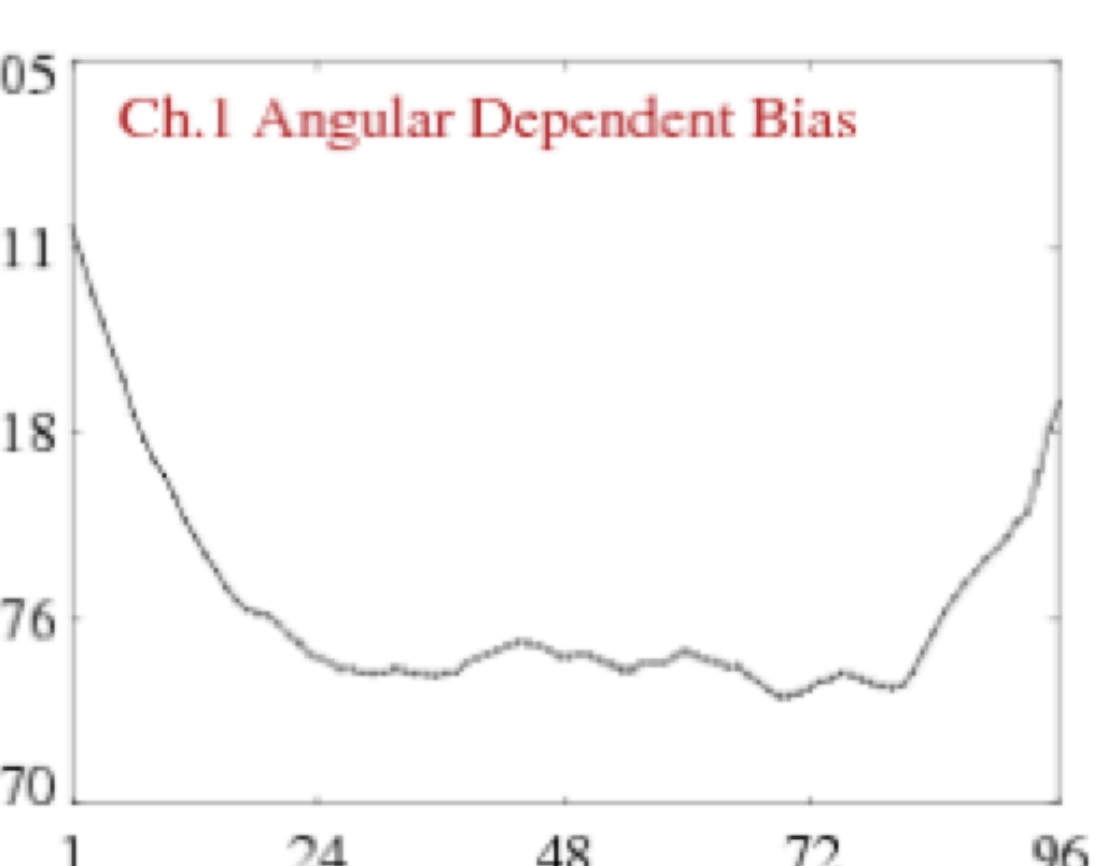
$$\Delta R_s^{Qv} = (R_{rfl} - R_v) \cdot \varepsilon_h + [(R_{rfl} - R_h) \cdot \varepsilon_v - (R_{rfl} - R_v) \cdot \varepsilon_h] \cdot \sin^2\theta - \frac{R_3}{2}(1 - \varepsilon_h)^3 \cdot \sin 2\theta$$

$$\Delta R_s^{Qh} = (R_{rfl} - R_v) \cdot \varepsilon_h + [(R_{rfl} - R_h) \cdot \varepsilon_v - (R_{rfl} - R_v) \cdot \varepsilon_h] \cdot \cos^2\theta + \frac{R_3}{2}(1 - \varepsilon_h)^3 \cdot \sin 2\theta$$

Simulated ATMS Channel-1 Bias



Real ATMS Channel-1 Bias



Conclusion

The impact of antenna emissivity on Earth scene includes two parts: 1) extra error will be introduced into calibration equation due to uncorrected antenna emissivity on calibration target, and 2) the calibrated earth scene brightness temperature will be contaminated directly by the reflector thermal radiation if not corrected. An error model was developed for evaluation the impact of the first part, study results show that the calibration error decrease with increased scene temperature. For K band, calibration error can be as large as 1.5K at 2.7K space view, and decrease to -0.1K at 300K Earth scene observation. Since the different nonlinearity characteristic at ATMS channels, the magnitude of calibration error at different channel is also different.

To assess the impact of second part, full stokes vector RT model is required, which is the work need to be carried out in future.

References

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