**GSICS Microwave Subgroup Meeting Minutes**

**1200-1400 (UTC)** **16 February 2021**

**Attendees:** Xiaohai Cui, Donglin Meng, Philip Rosenkranz,Quanhua “Mark” Liu, Qifeng Lu, Cheng-Zhi Zou, Ed Kim, Robbie Iacovazzi, Manik Bali, Jian Shang, Shengli Wu, Misako Kachi, Fabien Carminati, Hu Yang, Martin Burgdorf, Viju John, Paul Poli, Karsten Fennig, Vinia Mattioli, Tony Reale, Hu JI, MCL, Tim Hewison, Yalei You, Guo Xiaotao, Rachael Kroodsma

**Information given during the presentations is not reflected in the notes. See presentations for information.**

**1)** **Introduction (Co-Chairs Qifeng Lu (CMA) and Mark Liu (NOAA))**

Meeting is focused on traceability.

**2) Traceable measurement technique and measurement capability for power on the microwave and millimeter frequency ranges (Xiaohai Cui from NIM (National Institute of Metrology, China))**

*Qifeng* - Your last slide (slide 46). Do demonstrate how microwave power can be measured and an uncertainty placed on those measurements. Do you have examples of how these methods may have been applied to a satellite instrument? Your discipline is not that familiar to the GSICS Microwave Subgroup audience.

*Xiaohai* - Standard provide traceable measurement for different devices, and different measurement parameters. One example is satellites that want to implement higher frequency communication. Found a problem when trying to apply calculated estimates of radiant energy power of from a communication satellite. There seemed to be a loss of power in the communication satellite, which manifested as a signal transmission distance that was lower than expected. It was discovered that the measurements of power deviated from SI traceable measurement. If an satellite make wants to make sure that their system will work properly, in the absence of SI traceable power measurements, they may have to increase the power by a certain margin to offset non-SI traceable measurements. That of course increases cost.

*Tiger* – Important for the future SI traceable calibration of microwave radiometer. Aspects of SI traceable calibration are the connection of the power sensor to the power generator, and the calorimeter to the power sensor. Where do you get the signal generator and power sensor? For the signal generator and power sensor, can you make your own?

*Xiaohai* – Power generator and power sensor are separate. We use a commercial generator. Frequency range is lower than 70 GHz,then use a double amplifier to go above 140/170 GHz or higher.

*Tiger* - After you amplify signal for the higher frequency, how do you know the stability and accuracy are the same.

*Xiaohai* – Use a coupler with feedback to control the amplifier. Use feedback loop to control the stability. Better than 0.1% in 24 hours. It is very stable. Use designed a stabilizer that is much better than a commercial stabilizer.

*Tiger* - What kind of transmission wire do you use to measure this high frequency signal?

*Xiaohai* – Just a waveguide. W6 W3 WR5 cover the frequency range.

**2) Metrology of Antenna Radiation Pattern (Donglin Meng from NIM (National Institute of Metrology, China))**

*Tiger* – Go back to slide 14. Results that we are seeing are between different method or institute. Results within the elevation angle, +- 50°, are very consistent. At higher elevation angles, there is a big difference in the measurement. Which one is the correct one? Which one is more accurate? What is the root cause for Planar Near Field (PNF) and Spherical Near Field (SNF) results discrepancies? There is a very different noise floor for the measurements beyond 50° elevation. Why? Which one is correct?

*Donglin* - For this antenna, we do not have the standard value. Strictly speaking, we don’t know which is good or correct. Just demonstrate the difference between results given for different methods and institutions. Left photo shows far field method has much stronger response ripples. The SNR of the sidelobe level for the far field method is not as good as in the main lobe. The SNF method is considered to have better range than the PNF method. The PNF method is suitable for a high directivity antenna. The main lobe is in close agreement with the SNF method, but the nature of the planar near-field method will cause a big discrepancy between the PNF and SNF methods beyond the main lobe. We think SNF is superior.

*Tiger* – If no reference antenna pattern, we cannot tell which one is correct. If the wrong antenna pattern is used in calibration, results will be very different. Antenna pattern measurements in the sidelobes are critical, and not just the main beam. Which one is correct?

How do you determine how much difference in the antenna solid angle? From the near field and far field, how much difference can there be between the measurements?

*Donglin* - Don’t have the result. It could be 20% or less.

For radiation pattern calibration, we do not need any reference antenna pattern, because the radiation pattern of a probe is relatively easier to be calibrated with a far-field method, and for the spherical near-field (SNF) method, the radiation pattern of an open-ended waveguide probe has less effect on the final results. The major concerns for SNF are the careful alignment of the probe, and the alignment of the roller axis and azimuth axis. That is why I emphasize the alignment system for a SNF facility.

 Yes, you are right, antenna pattern measurements in the sidelobes are also critical, and not just the main beam. My comment is that the SNF is suitable for measuring the whole 3D pattern, not only the main lobe. The uncertainty from SNF could be the obstructing of the positioner, which will cause errors to the backlobe. Generally speaking, the higher of the directivity of the antenna under test, the less uncertainty from the PNF.

As for the difference of the antenna solid angle measured with different methods, it depends on the antenna types. For a very high directivity antenna, near-field method is better than far-field method, and SNF is better than a PNF. However, the alignment of SNF is more critical than that of a PNF.

*Phil* – Can you tell me which curve is the outlier in slide 14? Is CAST\_PNF is an outlier?

*Donglin* - PNF is only good for high gain antenna. The theta angle greater than 40 deg elevation will be beyond the scope of PNF method. It should be deleted, but left for demonstration.

**3) Space-based Microwave Reference Radiometer (Philip Rosenkranz from MIT)**

*Ed Kim* – Traceability of RO is related to a frequency standard. Would there be an advantage for temperature traceability of an on-orbit instrument to a ground Kelvin reference standard?

*Phil* – Speaking only hypothetically, and it would depend on the details.

*Robbie* - I thought the profile of temperature and water vapor were created from a retrieval algorithm that requires a first guess, how would the uncertainty of this be figured into a temperature retrieval?

*Phil* – (Gives explanation of physics of Doppler shift and how it relates to refractivity.) There is a first guess at the highest altitude, then “onion-peeling” (or Abel transform) yields a refractivity profile, which depends on temperature and moisture. The rms errors shown on the slide relate to inference of radiometric brightness temperature, given the refractivity profile.

*Mark* – For the calibration reference radiometer, what kind of instrument should this be?

Phil – Go back to slide 3. Dual polarization is useful for comparison with an instrument like ATMS. This diagram shows the horn antenna rotating along with the radiometer. In that way, to avoid the use of the reflector, you can get very low side lobes, and antenna pattern can be calculated relatively accurately at high angles.

*Cheng Zhi* – Desirable feature includes low sidelobe antenna? 2%-4%? What is low?

*Phil* – What is achievable using the conventional definition of beam efficiency (there are different criteria), is a 1% power outside of the main beam. A more important number – the power received from off the earth – e.g., cold space - when looking at nadir could be as low as 0.03 %. This would be beyond 60 degrees from the boresight.

*Tony* - I understand that the Tdry available from GPSRO can serve as a reference temperature measurement in the stratosphere (where it is dry); can you comment on utility of collocated GPSRO, GCOS Reference Upper Air Network (GRUAN; radiosonde), polar satellite radiometer in context of polar sensor monitoring?

*Phil* - The difficulty in comparing GPSRO with a satellite radiometer like ATMS (which doesn't see the Earth limb) is just that the measured atmospheric paths are different, thus they are different averages. That's why a reference radiometer's scan should include the limb. But all of those comparisons are useful to some extent.

**4) Radio Frequency Interference (RFI) in Microwave Instrument Measurements (Ed Kim from NASA)**

*Mark* - List frequency for potential auction in US. Do other countries do similar things? Do they do an auction?

*Ed* – The ITU … all countries get together at World Radio Conferences and decide which block of frequencies will be available for auction. For example, for 5G, a block of band is decided, and each country may operate 5G at slight different frequencies with respect to another. The country may not use the band at all. Not going to see frequencies that are dramatically different from frequencies decided on by the ITU. These are international agreements.

*Mark* – Concerned about the 50-60GHz region, which is our sounding region. Do we need an international effort to launch a service satellite that would map RFI? Then the satellite operators would know the geographic distribution of RFI signals.

*Ed* - If you had such a sensor, that would be great. It would help quanity the RFI. The error bars are quite large. The 5G systems around 24 GHz are not turned on globally yet. More and more will start turning on in the next few years. Included backup slides from IGARSS that had information from WRC-19. If you had RFI measuring satellites, the observations would be interesting, but how useful they are would depend on how sensitive the instruments are. If you think about who would actually execute this runs into problems. Such programs run into cost issues.

*Tiger* – You mention that onboard sensing and processing of RFI may be good option, but too late for J4. Possible solutions for current operational radiometers, and the future ones that cannot be changed?

*Ed* - Yes, a digital processor would be the most powerful tool to deal with the problem. Nobody will change the design of ATMS, as they are under construction. So, if you will add RFI capability to sounders, it will have to be added to future radiometers that are just beginning their design right now.

*Robbie* – If we are thinking about smaller sounders – e.g., cubesats – will this kind of technology be an option?

*Ed* – Everything is smaller. If you want to add a digital processor and get it to fit within power constraints poses a challenge. May have to move to instruments that are a little bigger than a Cubesat. Don’t need something as big as ATMS.

T*iger* – Some smallsats are digitized. For example TROPICS.

*Ed* - Not sure how much it can do. It has been demonstrated to a marginal degree. But for all channels the beam widths gets large and it becomes difficult … need a more powerful processor. More space.

*Donglin* – Can the Starlink satellite cause RFI to remote sensing instruments? It uses 11.7 GHz.

*Ed* - That is much lower than most sounders use. Don’t expect interference from an 11 GHz signal. On the other hand, the second or third harmonic could be a problem.

**5) Atmospheric Temperature FCDR from the MSU/AMSU/ATMS: Recent Progresses (Cheng-Zhi Zou from NOAA)**

*Manik* – GSICS is trying to establish FCDR as one of the standards, and we are preparing a document about this. Could you add a few lines in the document about changes you have made to the FCDR?

The FCDR that is public, are these changes incorporated into that?

*Cheng-Zhi* – Not yet. The early version is available for multi-channels. For the current version, we treating this CDR as an intermediate product associated with TCDR. Only can do a few channels because of staffing deficiencies. Need another project to recalibrate all these channels using new references. We will publish the coefficients soon … within a year. New coefficient may be put on website. Need a new agreement with NCEI to transfer to them. This agreement is not in place. Need a project and funding support for that.

*Manik* - You are doing SNO between Metop-A AMSU and ATMS. Is the SNO restricted to small temperature range?

*Cheng-Zhi* – We did not do inter-calibration between ATMS and Metop-A AMSU-A. They are both compare really well with each other and are very stable. No need to inter-calibrate with each other. Trend difference is within the 0.04K/decade requirement.

*Martin* – If you say there are not trend differences between ATMS and AMSU-A. Is it really certain that they would have a different trend? Can it be that they both have the same trend because they are similar instruments?

*Cheng-Zhi* – It is not identical, but the trend between them is small 0.01K/decade. Assume no trend between them. Calibration is of high quality.

*Martin* – These instruments may have the same trend. The reasons you gave in regards to why there could be a trend in the offset, this reason could be valid for both instruments.

Cheng-Zhi - For the Metop-A and ATMS we don’t assign time varying coefficient. The coefficients are original for the instrument. For ATMS this is the same. It is a reference satellite. For the other satellites that are not a reference satellite, they are given coefficients to change the bias.

*Tiger* –How do you evaluate instrument degradation. Need some sort of independent reference. Could use lunar.

*Cheng-Zhi* – Thinks this is important.

*Tiger* - For original AMSU data set, did you use TDR or SDR.

*Cheng-Zhi* – We use the TDR data, so we don't apply an antenna correction. Antenna correction adds a constant bias to the original antenna temperature, and we try to limit bias sources. SDR would be an added source of bias we would have to eliminate.

*Robbie* – Have you considered comparing your results with radio occultation? You are using SNO.

*Cheng-Zhi* – It would definitely have a bias. The community usually works to compare the bias *trends* from 2002. There is a paper that is out that performs comparison of microwave sounder trends using different methods: Steiner, A.K. et.al., 2020: Observed temperature changes in the troposphere and stratosphere from 1979 to 2018, Journal of Climate, Vol. 33, 8165-8194.

**6) GSICS Annual Meeting Discussion (Manik Bali)**

There is a pre-planning meeting on Thursday, and the Annual Meeting planners would like members of the MW subgroup to make it. The annual meeting will be a web meeting, and will try to replicate the format of the previous year … well, maybe not exactly. For the microwave there is a breakout session, and that typically is a full day. Recommend that we plan a session for the microwave. The planning committee needs a brief outline of topics we want to cover? Just an overview of where we are, where we were, future work, etc. Good progress has been made, and let everyone needs to know about it.

*Qifeng* – When is the meeting?

*Manik* - Last week of March.

*Mark* – For microwave, we need to discuss do we have a two day meeting?

*Qifeng* – Last year we are totally moved to virtual conference. We had a two day meeting, and we could have that this year. We have technical meeting in March, regarding applications of mw sounder and imager. We can invite talks to give a general overview of progress. Could also have technical meeting together.

*Mark* - We can still have two day meeting: One day for general report (summary, activity update and future plan), and the next day would be technical presentation.

*Manik* - Web meeting is shorter than annual meeting. Overall length of the MW can be shortened because we are having online meetings.

*Mark* – Are you thinking one day or two days?

*Manik* - One day is too much. Maybe 5-6 talks discussing major developments in the subgroup and leave the floor open for some talks.

*Robbie* – We have been sticking to themes for the Subgroup meetings. Can our technical session be our planned March meeting?

*Manik* - Theme – Lunar cal, FCDR, and some talks could be combined. This could be used to summarize progress.

*Qifeng* - Last week of March is GSICS AM. For microwave subgroup, one day may be sufficient. Each subgroup has one day, but most days we gather as a community. Technical meeting can be moved to another week.

*Mark* – For the last week of March … is this time for parallel or plenary sessions.

*Manik* - Everything is flexible. Main thing is how we did it last year. Overlapping times are difficult to attend.

*Qifeng* - We can plan after the meeting on Feb 18th. We will organize several talks to report our progress of our Subgroup. We will plan to have summary topics at the Annual Meeting, and hold a separate technical meeting apart from the Annual Meeting in a different week.

ACTION: Organize summary topic presentations for the Annual Meeting.