Status of GOSAT-GW and AMSR3

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The Joint PI Meeting of JAXA Earth Observation Missions FY2021

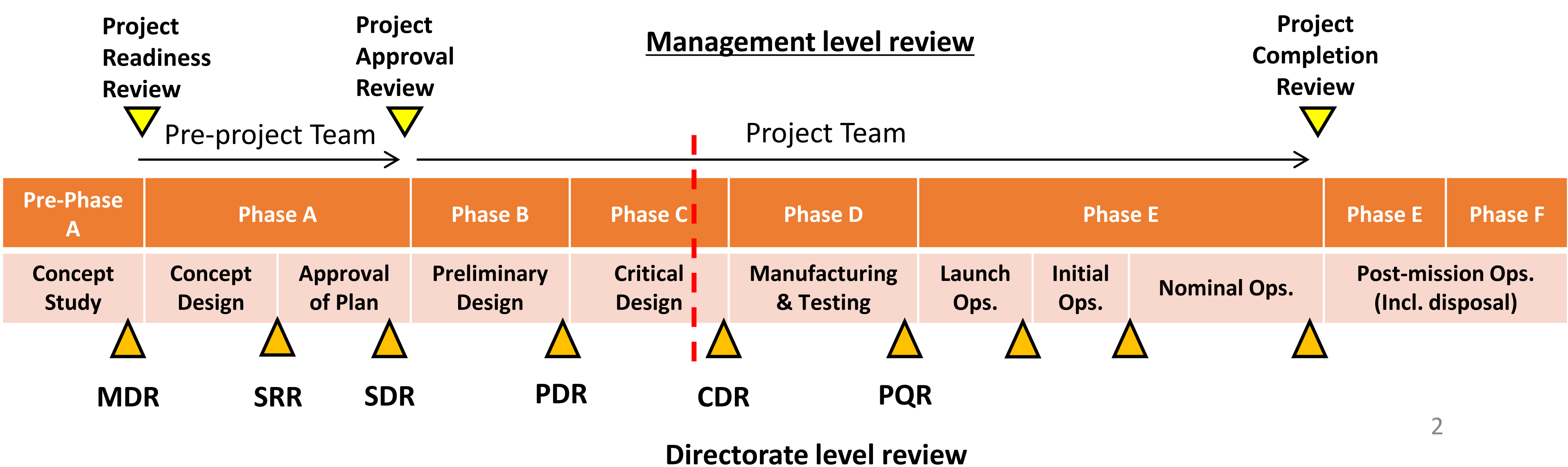
< Status of GOSAT-GW >

- Jun. 2018: Mission Definition Review (MDR)
- Jul. 2018: Project Readiness Review (management review)
- Dec. 2018: System Requirement Review (SRR)

  ~Selection of the prime contractor~
- Oct. 2019: System Definition Review (SDR)
- Nov. 2019: Project Approval Review (management review)
- Dec. 2019: Started GOSAT-GW* Project

  *Global Observing Satellite for Greenhouse gases and Water cycle
- Mar. 2021: Preliminary Design Review(PDR)

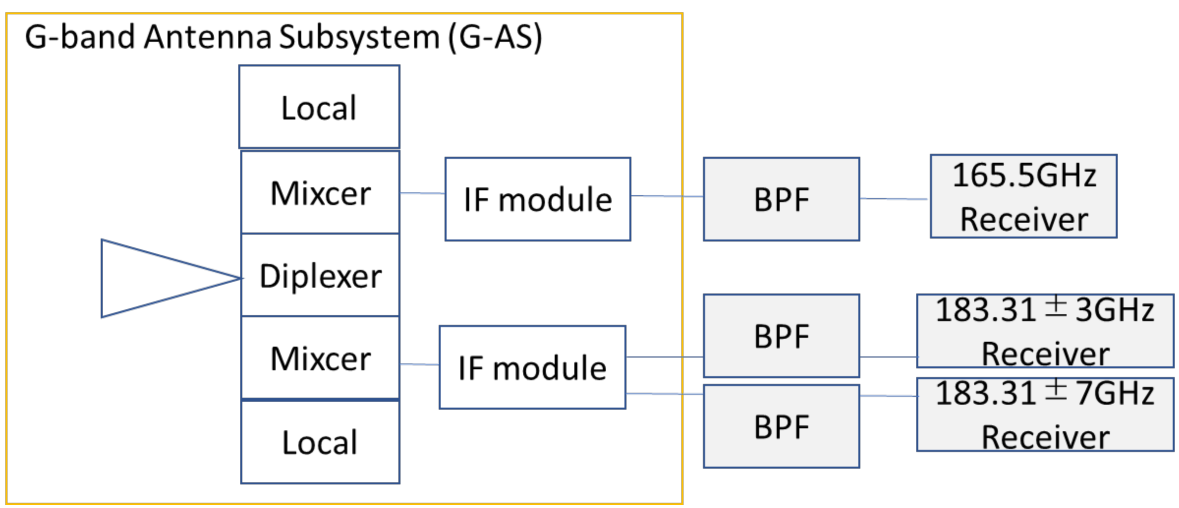
Critical Design phase(Phase C) is in the process.



＜Status of AMSR3＞

Based on the results of the critical design and development tests, the AMSR3 CDR was held in October 2021, and the flight model is now being manufactured and tested.

- Main topics on the CDR
  - Nonlinearity of AMSR3 receiver
    - ✓ See Next page
  - G-band channel
    - ✓ Currently, prototype evaluation of some of G-AS modules is in the progress. Based on the evaluation results, G-band design verification meeting will be held to confirm its conformance to the system specification for the G-band. (For G-band system specifications, see pp.5-7)

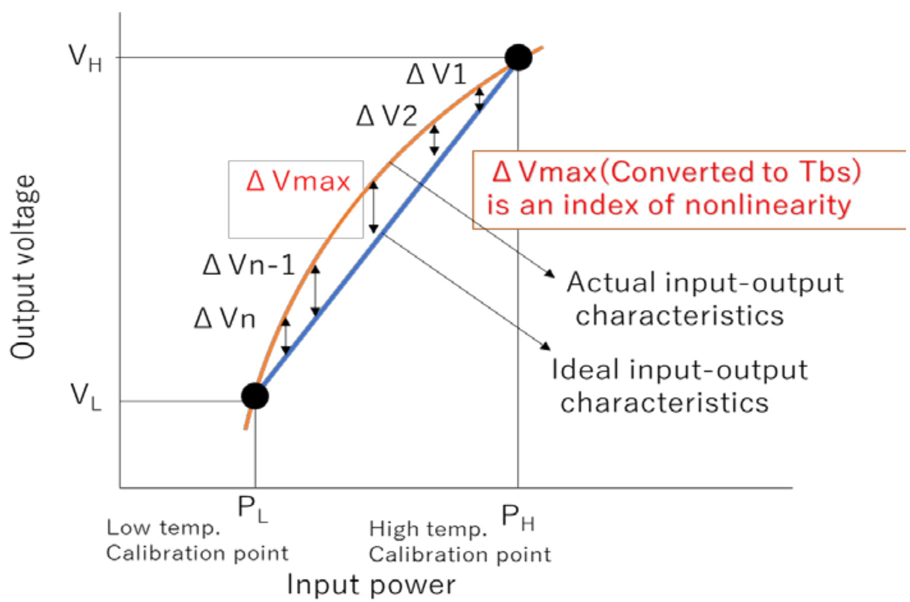


➢ Nonlinearity of AMSR3 receiver

- ✓ Nonlinearity of the receiver is one of the main causes of the brightness temperature (Tbs) bias error. In AMSR2, the main cause of bias error is considered to be overcorrection of nonlinearity. (*)

  (*) EORC/JAXA, "Results of intercalibration between AMSR2 and TMI/AMSR-E (AMSR2 Version 1.1)", May 8, 2014

- ✓ In AMSR2, Continuous wave (CW) is used as the input signal for nonlinearity. However, it was confirmed that there is a difference in nonlinearity between CW and noise input (Noise).
- ✓ Therefore, AMSR3 uses Noise with bandwidth close to that of the actual observation signal as the input signal. This makes it possible to obtain accurate nonllinear characteristics.



Explanation of nonlinearity

Example of measurement result of AMSR3 Receiver EM

	Input signal type	Result
Non-linearity	CW	1.01K
	Noise	0.62K

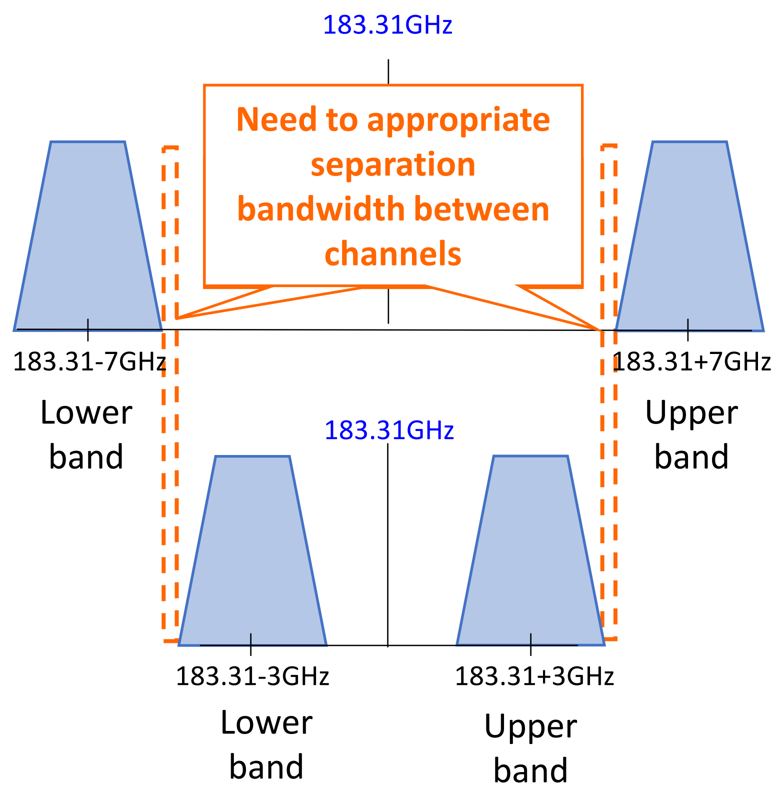
CW input shows larger nonlinearity

Specifications for G-band channels

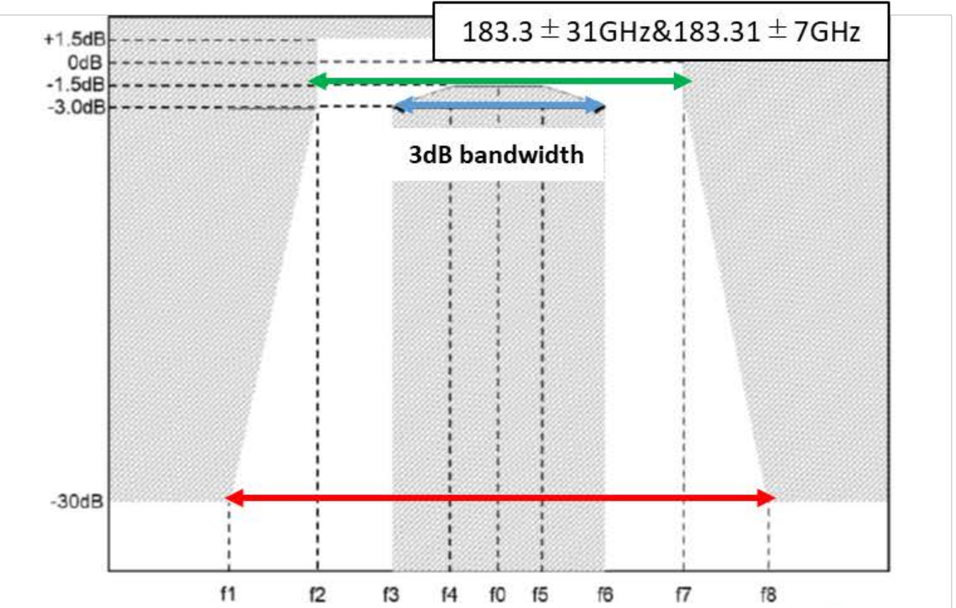
Item	Specification	Remarks
Overlap (Negative number rate means underlap)	166GHz: EL direction -22% 183GHz: EL direction -35%	Explained at he FY2020 PI workshop as a result of the 183GHz design (See Appendix pp. 19-20)
Beam width (IFOV Az × El)	166GHz: Azimuth=0.23° Elevation=0.30° (4km × 9km) 183GHz: Azimuth=0.23° Elevation=0.27° (4km × 8km)	Explained at the FY2020 PI workshop (See Appendix pp. 19-20)
Incidence angle	About 52°	
Main beam efficiency	Above 85%	
Side-lobe peak	Less than -15dB	
Cross polarization	Less than -15dB (TBD)	Will be evaluated in the design verification meeting
Frequency response characteristics	See pp.6-7	

➢ Frequency response characteristics

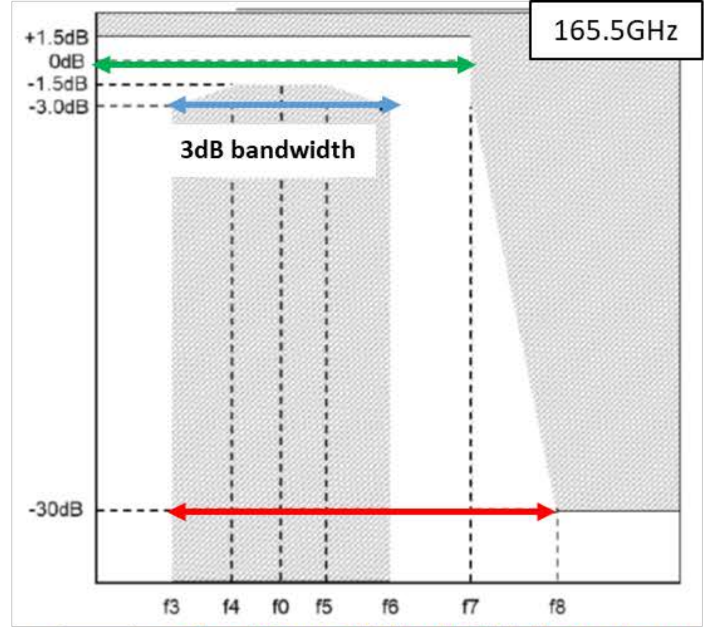
In order to obtain independent information on the vertical direction of water vapor, which is one of the observation objectives of 183 GHz, the specifications have been determined to allow appropriate bandwidth separation between 183GHz channels. (See next page）



Frequency relationship between
183.31 ± 3 GHz and 183.31 ± 7 GHz channels



The minimum 3dB bandwidth that can be specified.(f6-f3)
The maximum 3dB bandwidth that can be specified(f7-f2)
The maximum 30dB bandwidth that can be specified(f8-f1)



The minimum 3dB bandwidth that can be specified.(f6-f3)
The maximum 3dB bandwidth that can be specified(f7-f3)
The maximum 30dB bandwidth that can be specified(f8-f3)

The 3dB bandwidth of AMSR3 is almost equal to or narrower than that of GMI.

	AMSR3 3dB bandwidth	GMI 3dB bandwidth	AMSR3 Maximum 30dB bandwidth
165.5GHz	3200-3580MHz (f6-f3)-(f7-f3)	3850MHz*1	4000MHz (f8-f3)
183.31 ± 3GHz (one side)	1470-1880MHz (f6-f3) -(f7-f2)	1486MHz*2	2600MHz (f8-f1)
183.31 ± 7GHz (one side)	1700-1880MHz (f6-f3) -(f7-f2)	1880MHz*2	2600MHz (f8-f1)

*1:David W. Draper, "TERRESTRIAL AND SPACE-BASED RFI OBSERVED BY THE GPM MICROWAVE IMAGER (GMI) WITHIN NTIA SEMI-PROTECTED PASSIVE EARTH EXPLORATION BANDS AT 10.65 AND 18.7 GHZ", 2016 Radio Frequency Interference (RFI)
*2:"Precipitation Processing System(PPS) NASA Global Precipitation Measurement(GPM) Microwave Imager (GMI) Level 1B(L1B) Algorithm Theoretical Basis Document(ATBD) Version 2.3", February 2016

＜Status of AMSR3 L1 processing software＞

- In parallel with the AMSR3 CDR(October 2021), a design verification meeting was held for the L1 processing software for creating AMSR3 Level 1 brightness temperature products (L1 products), and the production of the development test version of the software for the interfacing test with the mission operation system has been started.

- The format of L1 products in consideration of common use with the higher-order products and Radio Frequency Interference (RFI) identification method(*) are also being considered.

  (*) In AMSR2, RFI identification is performed for 6.925GHz and 7.3GHz (C-band). In AMSR3, <u>it will also be performed for 10.25GHz and 10.65GHz (X-band) because 10.25GHz is newly added in AMSR3.</u>

AMSR3 Standard Products (1/3)

Product newly defined in AMSR3 is denoted as “N”, one upgraded from AMSR2 research product is denoted as “U”, one improved accuracy from AMSR2 is denoted as “I” in Category field.

Category	Product Name	Stored Parameter	Area	Spatial Resolution	Range	Release Accuracy	Standard Accuracy	Note
	Brightness Temperature (L1B)	Brightness Temperature (6-89GHz)	Global	5-50 km	2.7-340 K	±1.5 K	±0.3 K	TB differences between Asc. and Dsc. orbits after removing bias based on AMSR2 or TB estimate from numerical prediction model over ocean & in clear sky condition. Requirements for high-frequency channels (center frequency, band width etc.) is equal to that of GMI.
N		High-frequency Brightness Temperature (166,183GHz)	Global	10 km	2.7-340 K	±1.5 K	±1.0 K	
	Resampled Brightness Temperature (L1R)	Brightness Temperature (6-89GHz)	Global	5-50 km	2.7-340 K	±1.5 K	±0.3 K	
N		High-frequency Brightness Temperature (166,183GHz)	Global	10 km	2.7-340 K	±1.5 K	±1.0 K	
I	Total Precipitable Water (TPW)	Total Precipitable Water over ocean	Global Ocean	15 km	0-70 kg/m^2	3.5 kg/m^2	3.0 kg/m^2	RMSE to GPS and/or sonde observation.
N		Total Precipitable Water over Land	Global Land*	15 km	0-70 kg/m^2	6.5 kg/m^2	3.5 kg/m^2	RMSE to GPS and/or sonde observation. * Sparse vegetation area
	Integrated Cloud Liquid Water Content (CLW)	Integrated Cloud Liquid Water Content	Global Ocean	15 km	0-1.0 kg/m^2	0.10 kg/m^2	0.05 kg/m^2	RMSE to optical imager observation.

The changes from FY2020 in blue

AMSR3 Standard Products (2/3)

Product newly defined in AMSR3 is denoted as "N", one upgraded from AMSR2 research product is denoted as "U", one improved accuracy from AMSR2 is denoted as "I" in Category field.

Category	Product Name	Stored Parameter	Area	Spatial Resolution	Range	Release Accuracy	Standard Accuracy	Note
	Precipitation (PRC)	Liquid Precipitation	Global	15 km	0-20 mm/h	Ocean 50 % Land 120 %	Ocean 50 % Land 120 %	Relative error to GPM/DPR and/or ground radar network in 0.5-degree equivalent grid.
N		Solid Precipitation	Global	10 km	0-4 mm/h	Ocean 130%* Land 200%*	Ocean 130%* Land 200%*	Relative error to GPM/DPR and/or EarthCARE/CPR in 0.5-degree equivalent grid. * Evaluate with monthly precipitation more than 1mm/month.
	Sea Surface Temperature (SST)	6GHz Sea Surface Temperature	Global Ocean	50 km (6GHz)	-2 -35 ℃	0.8 ℃	0.5 ℃	RMSE to buoys observation.
U		10GHz Sea Surface Temperature		30 km (10GHz)			0.6 ℃	
U		Multi-band Sea Surface Temperature		30 km (6+7+10GHz)			0.6 ℃	
	Sea Surface Wind Speed (SSW)	Sea Surface Wind Speed	Global Ocean	15 km	0-30 m/s	1.5 m/s	1.0 m/s	RMSE to buoys observation.
	All-weather Sea Surface Wind Speed (ASW)	All-weather Sea Surface Wind Speed	Global Ocean	50 km	0-70 m/s	7 m/s	5 m/s	RMSE to dropsonde observation (winds speed more than 15 m/s).

AMSR3 Standard Products (3/3)

Product newly defined in AMSR3 is denoted as “N”, one upgraded from AMSR2 research product is denoted as “U”, one improved accuracy from AMSR2 is denoted as “I” in Category field.

Category	Product Name	Stored Parameter	Area	Spatial Resolution	Range	Release Accuracy	Standard Accuracy	Note
	Sea Ice Concentration (SIC)	Sea Ice Concentration	Polar Ocean	15 km	0-100 %	10 %	10 %	RMSE to optical imager observation.
U	High-resolution Sea Ice Concentration (HSI)	High-resolution Sea Ice Concentration	Polar Ocean	5 km	0-100 %	15 %	15 %	RMSE to optical imager observation.
	Soil Moisture Content (SMC)	Soil Moisture Content	Global Land	50 km	0-40 %	10 %	5 %	MAE to ground-based observation.
	Snow Depth (SND)	Snow Depth (Snow Water Equivalent)	Global land	30 km	0-100 cm	20 cm	20 cm	MAE to ground-based observation.

AMSR3 Research Products (AMSR3 only products)

Cate gory	Product Name	Area	Spatial Resolution	Range	Release Accuracy	Note	User Requirement
N	FOV-center Matched Brightness Temperature (L1C)	Global	5-50km	2.7-340 K	±1.5 K	TB differences between Asc. and Dsc. orbits after removing bias based on AMSR2 or TB estimate from numerical prediction model over ocean & in clear sky condition.	GSMaP
N	High-resolution Brightness Temperature (L1H)	Global	20-30 km	2.7-340 K	±1.5 K	6-89GHz only. TB differences between Asc. and Dsc. orbits after removing bias based on AMSR2 or TB estimate from numerical prediction model over ocean & in clear sky condition.	Meteorology (JMA, NOAA, EUMETSAT, etc.)
N	High-resolution Sea Surface Temperature (HST)	Global Ocean	20 km*	-2 -35 ℃	0.8 ℃	RMSE to buoys observation. *Input high-resolution brightness temperature	Meteorology, Fisheries, Ocean Navigation, Science
	Land Surface Temperature (LST)	Global Land	15 km	0 - 50 ℃	Forest: 3 ℃ Non-dense vegetation: 4 ℃	RMSE to ground-based observation.	
	Vegetation Water Content (VWC)	Global Land	10 km	0 - 4 kg/m^2	1.0 kg/m^2	RMSE to optical imager and/or ground-based observations.	
	Thin Ice Detection (TSI)	Polar Ocean	15 km	N/A	80 %	Right answer ratio to optical imager and/or ground-based observations.	
	Sea Ice Moving Vector (SIM)	Polar Ocean	50 km	0 – 40 cm	3 cm/s	Output zonal/meridional components.	Polar navigation (NIPR), Science

Product that has user requirement will be determined to upgrade to standard product or make operational processing/distribution as research product by the launch

AMSR3 Research Products (Merged Products)

Product Name	Area	Spatial Resolution	Range	Release Accuracy	Note	User Requirement
Soil Moisture and Vegetation Water Contents based on Land Surface Data Assimilation (AMSR3 + Land model)	Global land(snow free area)	25 km	Soil Moisture Content: 0 – 40 % Vegetation Water Content: 0 -2 kg/m^2	Soil Moisture Content: 8 % Vegetation Water Content: 1 kg/m^2	MAE to ground-based and/or optical imager observations. Need improvements in computer capability.	

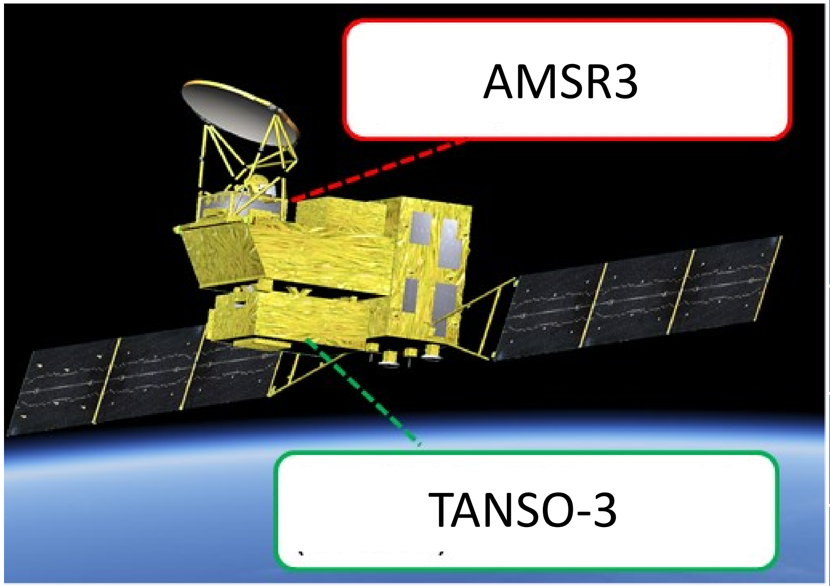
AMSR3 Research Products (Climate Data Record (CDR))

Product Name	Area	Spatial Resolution	Range	Release Accuracy	Period
Brightness Temperature CDR	Global	5-50 km	2.7-340 K	±1.5K	2002 – present
Total Precipitable Water CDR	Global Ocean	15 km	0-70 kg/m^2	3.5 kg/m^2	1987 – present
Integrated Cloud Liquid Water Content CDR	Global Ocean	15 km	0-1.0 kg/m^2	0.10 kg/m^2	1987 – present
Sea Surface Temperature CDR	Global Ocean	50 km	-2 -35 ℃	0.8 ℃	2002 – present
Sea Surface Wind Speed CDR	Global Ocean	15 km	0-30 m/s	1.5 m/s	1987 – present
All-weather Sea Surface Wind Speed CDR	Global Ocean	50 km	0-70 m/s	7 m/s	2002 – present
Sea Ice Concentration CDR	Polar Ocean	15 km	0-100 %	10 %	1978 – present
Snow Depth CDR	Global Land	30 km	0-100 cm	20 cm	2002 – present
Soil Moisture Content CDR	Global Land	50 km	0-40 %	10 %	2002 – present
Precipitation CDR (GSMaP Product)	Global	10 km	0-20 mm/h	Liquid Precipitation: Ocean 50%/Land 120 % Solid Precipitation: Ocean 80 %/Land 150 %	2000 - present

Appendix
(Excerpt from FY2020 PI Workshop)

Same slide as JFY 2019

＜Characteristics of GOSAT-GW satellite＞



Orbit	Type	Sun-synchronous, Sub-recurrent orbit
	Altitude	666km, recurrent cycle 3days (same as GOSAT)
	MLTAN	13:30±15min (same as GCOM-W)
Mass		2.6 ton (Including propellant)
Power		> 5.3 kW
Design life		> 7 years
Launch vehicle		H-IIA rocket
Mission data downlink rate		Direct transmission with X-band: 400 Mbps Direct transmission with S-band: 1 Mbps (Only for AMSR3)
Instrument		TANSO-3 AMSR3

＜Specification of AMSR3 Instrument＞

Sensor type	Conical scanning total power microwave radiometer
Antenna	Off-set parabolic antenna (ϕ 2.0m aperture)
Swath width	> 1530m
Quantization	12 bit
Incidence angle	55 deg. except 89GB, 166G,183G
X-polarization	< -20dB
Beam efficiency	> 90%
Range	2.7-340K
Sampling interval	5-10km
Data rate	87.4 kbps (average)
Life time	7 years

Center frequency [GHz]	Polarization	Band width [MHz]	NEDT (1σ)	Beam width (spatial resolution)
6.925 7.3	H/V	350	< 0.34 K	1.8° (34km x 58km)
10.25	H/V	500	< 0.34 K	1.2° (22km x 39km)
10.65	H/V	100	< 0.70 K	1.2° (22km x 39km)
18.7	H/V	200	< 0.70 K	0.65° (12km x 21km)
23.8	H/V	400	< 0.60 K	0.75° (14km x 24km)
36.5	H/V	1000→ 840	< 0.70 K (TBD)	0.35° (7km x 11km)
89.0 A/B	H/V	3000	< 1.20 K	0.15° (3km x 5km)
165.5	V	4000	< 1.50 K ~~(TBD)~~	0.3° ~~(TBD)~~ (6km×10km)→ (4km×9km)
183.31±7	V	2000×2	< 1.50 K ~~(TBD)~~	0.28 (TBD)→0.27° (5km×9km)→ (4km×8km)
183.31±3	V	2000×2	< 1.50 K ~~(TBD)~~	0.28 (TBD)→0.27° (5km×9km)→ (4km×8km)

Additional channels from AMSR2 in red

Changes from 2019 PI Meeting in blue

＜Change of bandwidth for 36GHz＞

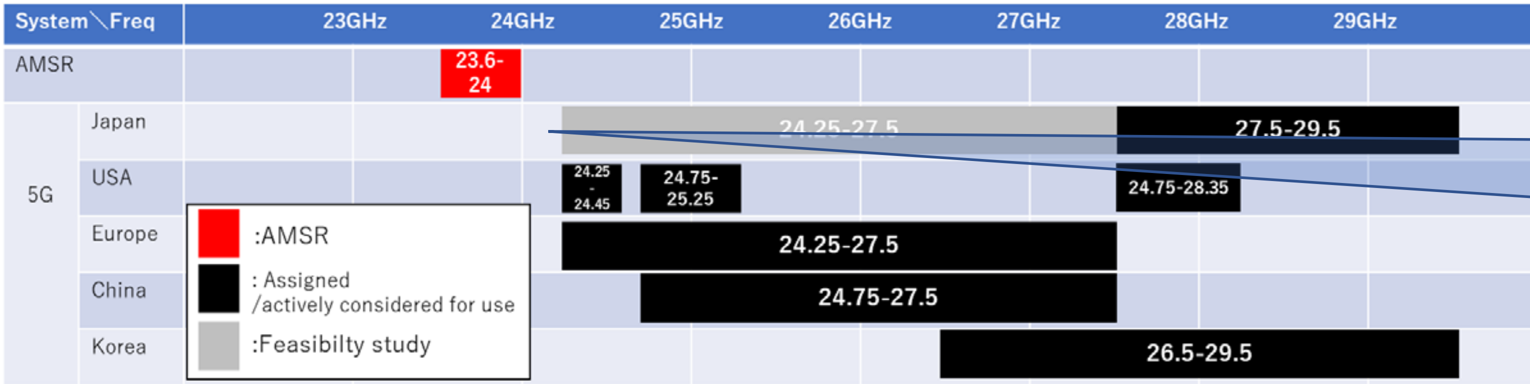
- As a result of the allocation of new frequency bands for the 5th Generation Mobile Communications System (5G) at the World Radio Conference (WRC-19), the frequencies used in the 23 GHz and 36 GHz bands of the AMSR series were close or adjacent to those of 5G as shown in the chart on the next page.

- JAXA evaluated necessity of the 5G countermeasure for AMSR3, which is under development, on the assumption that use of 5G will be widespread in the future. As a result of impact evaluation, the bandwidth, which will affect temperature resolution (NEΔT), of 36 GHz band needed to be narrowed in order to avoid the influence of 5G. On the other hand, its impact on 23 GHz will be negligible by improving the out-of-band frequency characteristics.

- JAXA interviewed the algorithm developers and users who directly use the brightness temperature products (July 31th ～August 21th, see Attachment 1), and received acceptable comments on the impact on bandwidth reduction.

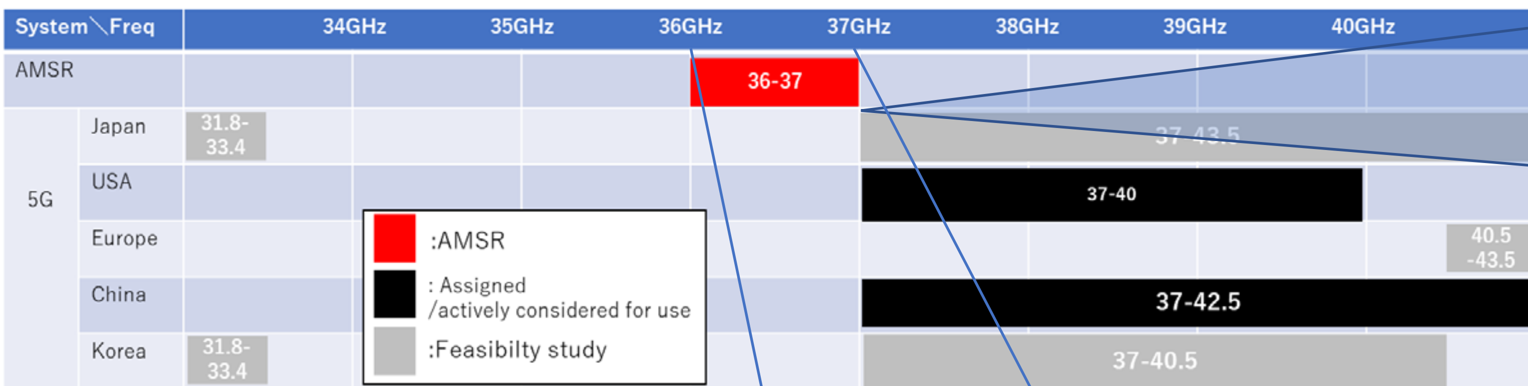
- After that, as a result of the study to minimize the reduced bandwidth, the bandwidth of 36 GHz was changed from 1000 MHz to 840 MHz . As for the temperature resolution, the value remains unchanged, but with TBD, and will be fixed with critical design results.

● AMSR3 and 5G allocated frequencies (22GHz ~ 30GHz)

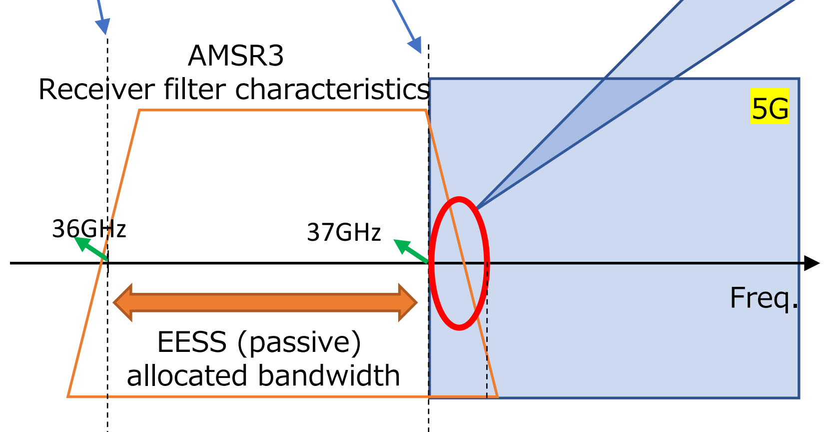


AMSR3 and 5G frequencies have a buffer band of 250 MHz (24.0 to 24.25 GHz)

● AMSR3 and 5G allocated frequencies (33GHz ~ 41GHz)



AMSR3 and 5G frequencies are adjacent to each other with no buffer band. Its impact cannot be avoided by improving the out-of-band frequency characteristics while maintain the bandwidth.



<Change of beam width (spatial resolution)for high-frequency channels>

- As a result of the preliminary design, the specification of beam width (spatial resolution) for high-frequency channels will be changed as shown in the table below. It will be finalized in the PDR.

Item	Before specification change	After Specification change
Beam Width (spatial resolution Az × El)	166GHz band：0.30° (5km × 10km) 183GHz band：0.28° (5km × 9km)	**166GHz band：0.30° (4km × 9km) 183GHz band：0.27° (4km × 8km)**

- The comparison of the spatial resolution and the overlap rate with GMI used as the reference for defining the AMSR3 specification is shown. The overlap rate decreased because of improvement of the spatial resolution, but it was kept better than the GMI.

Frequency	Spatial resolution		Overlap rate (Distance)
	Spatial resolution	Scanning Interval	
AMSR3 183GHz	4km × 8km	10km	-32%(※) (-2.5km)
GMI 183 GHz	4km × 5km	13.5km	-128%(※) (-7.6km)

(※) **Negative overlap rate means underlap.**

＜Change of beam width (spatial resolution)for high-frequency channels>

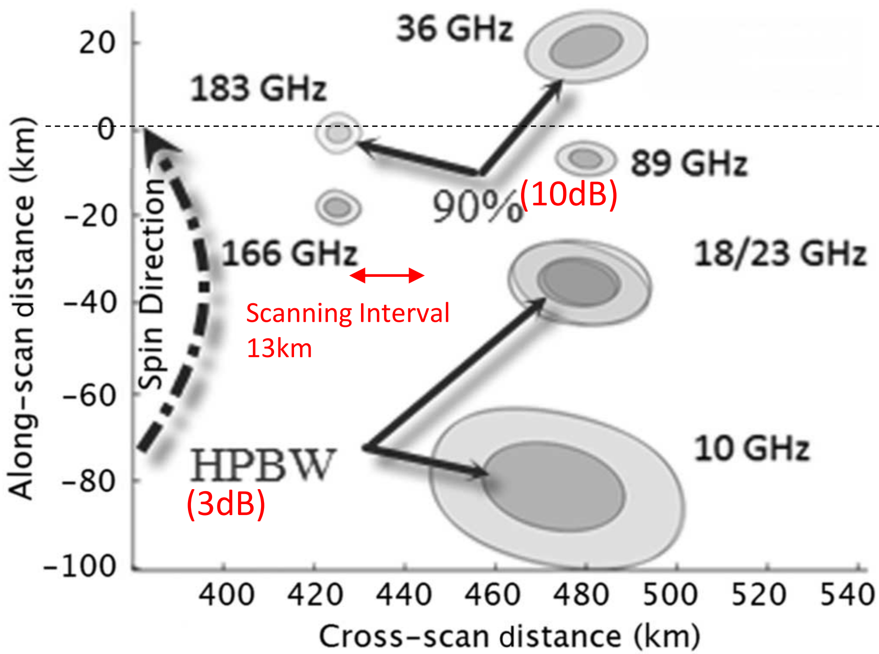
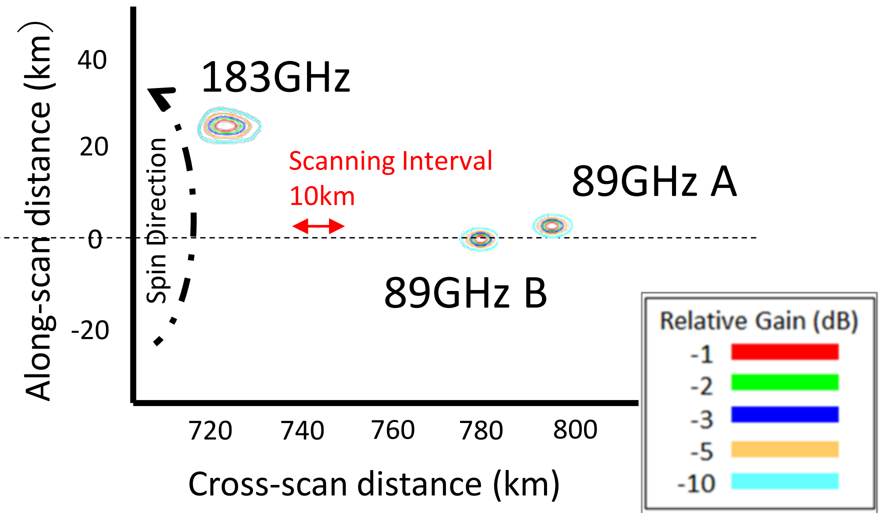


Fig.4. Earth IFOV in terms of HPBW and 90% power contour for the GMI at 407km altitude.

David W. Draper et al, “The Global Precipitation Measurement (GPM) Microwave Imager (GMI): Instrument Overview and Early On-Orbit Performance,” IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING, VOL. 8, NO. 7, JULY 2015.



AMSR3 IFOV(footprint)
(89GHz& 183GHz)
(Same scale as GMI)

IFOV(footprint) of GMI and AMSR3

<Addition of Brightness temperature product Level 1C>

In response to requests from users, Level 1C will be newly added as a research product. The Tables bellow are an overview of Level 1C.

<L1C Overview>

Processing Level	Definition	Explanation	Use (assumed)
Level 1C	A scene data product that stores the brightness temperature with the center position of the footprint matched by spatial matching processing of Level 1B brightness temperature for each frequency band.	At each observation point of 89.0GHz, the center position is aligned using the spatial matching process used in Level 1R. At that time, the footprint size is maintained at the original by using each antenna pattern of each frequency band.	Utilization of high-resolution data in the 89GHz band, such as precipitation algorithms.

<Stored data>

Type	6.925G H/V	7.3G H/V	10.25G H/V	10.65G H/V	18.7G H/V	23.8G H/V	36.5G H/V	89G-A H/V	89G-B H/V	165.5G V	183.3±3G V	183.3±7G V	Points	Resampling position
89GHzA	☆	☆	☆	☆	☆	☆	☆	●	☆	☆	☆	☆	486	Center position of all points in the 89GHz-A
89GHzB	☆	☆	☆	☆	☆	☆	☆	☆	●	☆	☆	☆	486	Center position of all points in the 89GHz-B

●: Original observation data

☆: Resampled data with the center position aligned.