Met Office

Level 1 processing for the Microwave Sounder on Metop-SG

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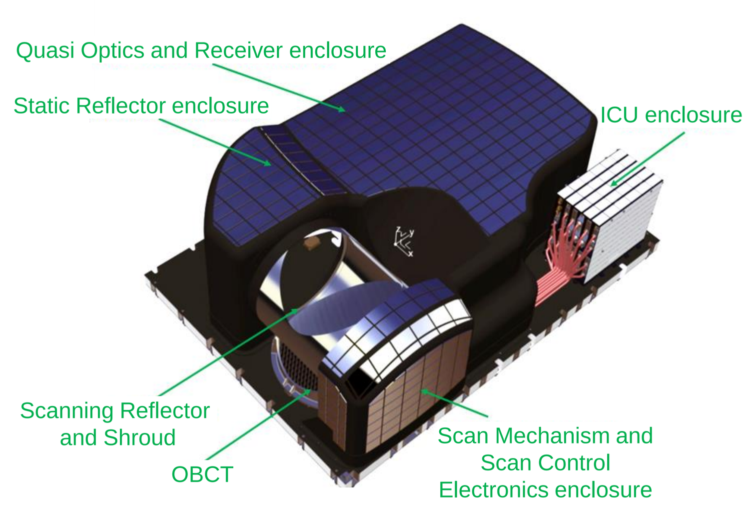
The Microwave Sounder (MWS) will be a key instrument on the Metop Second Generation series of satellites, due for first launch in 2021. The MWS Science Advisory Group (SAG) has been established jointly by ESA and EUMETSAT to advise on scientific issues related to the instrument and its processing – covering both pre-launch and post-launch activities. This poster introduces the instrument and describes some novel aspects of the level 1 processing that have been proposed by the SAG members.

The Microwave Sounder onboard Metop-SG Satellite A

The Microwave Sounder will provide information on atmospheric temperature and water vapour profiles, cloud liquid water, precipitation and surface properties. The MWS will contribute to primary mission objectives of the EPS-SG programme in the areas of Numerical Weather Prediction (NWP) and climate monitoring. In addition, MWS will provide services to atmospheric chemistry, operational oceanography and hydrology. The main users will be WMO real time users, i.e. NWP centres of National Meteorological Services, and ECMWF. The requirements are documented in [1].



The MWS is a traditional cross-track scanning microwave radiometer with 24 channels from 23 GHz to 230 GHz. It is designed to give improved performance compared with its predecessors (AMSU and MHS) particularly in the areas of radiometric noise, radiometric accuracy, spatial resolution and spectral coverage (particularly the new channel at 229 GHz, for ice cloud detection). It is implemented with a single main reflector (unlike AMSU and ATMS). Designed and manufactured by Airbus UK.

Channel	Centre frequency (GHz)	Bandwidth (MHz)	Polarisation	LO freq (GHz)	Footprint at nadir (km)
MWS-1	23.8	270	QH	Direct detection	40
MWS-2	31.4	180	QH	Direct detection	"
MWS-3	50.3	180	QH / QV	48.2	20
MWS-4	52.8	400	QH / QV	"	"
MWS-5	53.246±0.08	2×140	QH / QV	"	"
MWS-6	53.596±0.115	2×170	QH / QV	"	"
MWS-7	53.948±0.081	2×142	QH / QV	"	"
MWS-8	54.4	400	QH / QV	"	"
MWS-9	54.94	400	QH / QV	"	"
MWS-10	55.5	330	QH / QV	"	"
MWS-11	57.290344	330	QH / QV	55.0	"
MWS-12	57.290344±0.217	2×78	QH / QV	"	"
MWS-13	57.290344±0.3222±0.048	4×36	QH / QV	"	"
MWS-14	57.290344±0.3222±0.022	4×16	QH / QV	"	"
MWS-15	57.290344±0.3222±0.010	4×8	QH / QV	"	"
MWS-16	57.290344±0.3222±0.0045	4×3	QH / QV	"	"
MWS-17	89	4000	QV	Direct detection	17
MWS-18	165.5±0.725	2×1350	QH	82.75	"
MWS-19	183.311±7.0	2×2000	QV	91.655	"
MWS-20	183.311±4.5	2×2000	QV	"	"
MWS-21	183.311±3.0	2×1000	QV	"	"
MWS-22	183.311±1.8	2×1000	QV	"	"
MWS-23	183.311±1.0	2×500	QV	"	"
MWS-24	229.0±1.0	2×500	QV	114.5	"

Above: MWS channels as implemented. New channels (compared with AMSU/MHS) are shown in red. Spatial sampling is the same for all channels, i.e. low frequencies are over-sampled (like ATMS). Note: channels 3-10 and 11-16 have primary and backup receivers with opposite polarisations. RT models need to be able to accept either polarisation for each group of channels.

References

[1] EUMETSAT, EPS-SG End User Requirements Document [EURD], EUM/PEPS/REQ/09/0151

[2] NOAA KLM User's Guide, available at https://www1.ncdc.noaa.gov/pub/data/satellite/publications/podguides/N-15%20thru%20N-19/pdf/

[3] Fuzhong Weng and Hu Yang, Validation of ATMS Calibration Accuracy Using Suomi NPP Pitch Maneuver Observations, Remote Sens. 2016, 8(4), 332.

The radiometric calibration equations

We assume that incoming microwave radiation is reflected off an imperfect scan mirror of reflectivity R_θ, where θ is the scan angle. We also assume that there is a quadratic relationship between radiance, B, and counts, C:

$$a_0 + a_1 C + a_2 C^2 = (1 - R_\theta) B_{REF} + R_\theta B_{scene} \quad (1)$$

where the equation is valid for the earth scenes as well as the on-board black body (subscript *bb*) and the space view (*SP*). B_{REF} is the black-body radiance at the temperature of the reflector. There are several ways to solve this system of equations. However, we recognise that continuity with the existing AMSU/MHS approach (see [2]) is desirable – in which radiance is computed as a quadratic function of counts, and the coefficients are reported in the level 1B data. The following solution was devised, in which the new or modified terms (compared with AMSU) are ringed:

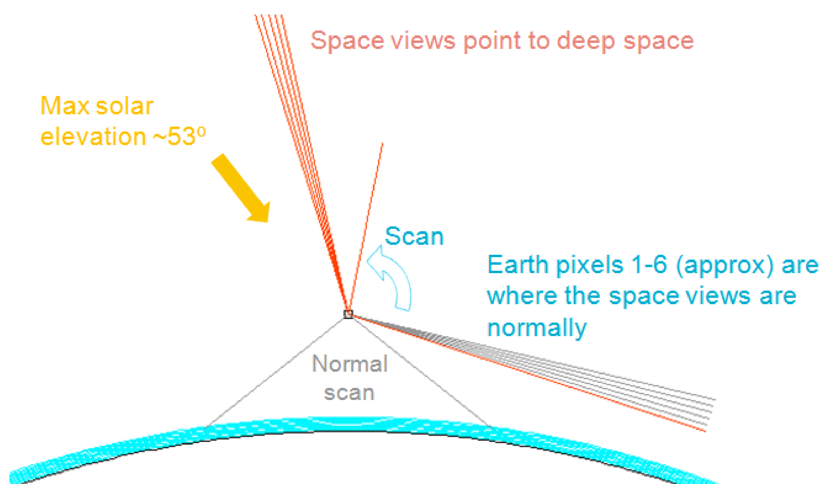
$$a_0 = B_{bb} R_{bb} - C_{bb} \frac{A}{G} + a_2 C_{SP} C_{bb} + B_{REF} (1 - R_{bb})$$

$$a_1 = \frac{A}{G} - a_2 (C_{bb} + C_{SP})$$

where $G = \frac{C_{bb} - C_{SP}}{B_{bb} - B_{SP}}$ (*gain*) and $A = \frac{R_{bb}(B_{bb} - B_{REF}) - R_{SP}(B_{SP} - B_{REF})}{B_{bb} - B_{SP}}$

Note that A is very close to 1. R_θ is to be characterised pre-launch and is planned to be verified during commissioning, via a spacecraft roll manoeuvre, similar to the pitch-over conducted for Suomi-NPP, see [3]. From theory, we would expect:

$R_{90} = R_0^2$ *QV channels* $R_0 = R_{90}^2$ *QH channels*

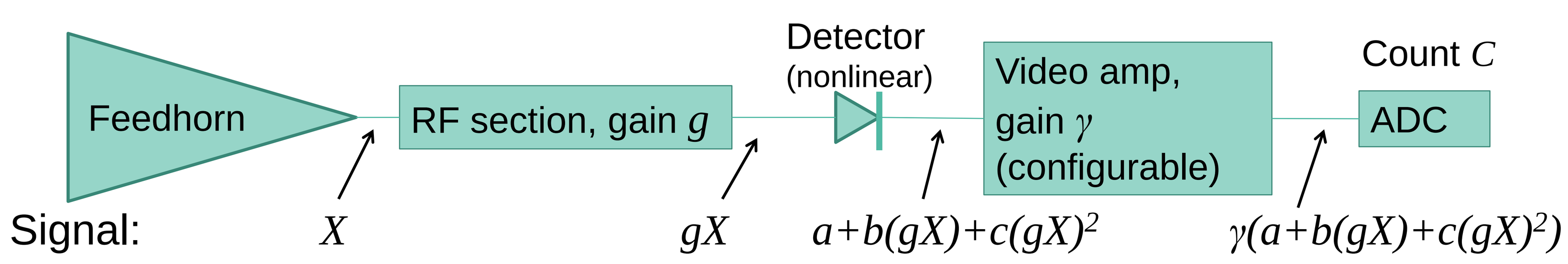


Geometry for a 120° roll manoeuvre

The roll manoeuvre will also allow validation of the pre-launch measurements of antenna sidelobes. The level 1 processor will take account of contamination of space views by the earth's limb and contamination of the earth views by cold space.

The non-linear term

It is usually stated that $a_2 = \mu / G^2$ where μ is constant over life of the instrument. Is this equation justified? Look at the receiver block diagram:



So d^2C/dX^2 is proportional to γg^2. But from equ (1) above, it can be shown that d^2C/dB^2 is proportional to $a_2/a_1^3 \approx a_2 G^3$ (ignore mirror reflectivity and assume a_2 is small). So $a_2 G^3$ is proportional to γg^2. Since $G = \gamma g$, a_2 is proportional to $1/(\gamma G)$, i.e.

$$a_2 = \frac{\mu}{\gamma G}$$

where μ is constant and has dimensions of *inverse counts* .

Only *changes* in γ matter, not the absolute value. Reported in the telemetry.

This differs from the classical formula – used for many instruments!

Although nonlinearity is expected to be small, the new formula should be more accurate as the receiver ages, i.e. if g changes with time.

Conclusions

The MWS instrument should give significant performance benefits compared with its predecessors. The MWS SAG is in the process of preparing a Science Plan, which will be publically available soon. The SAG has made recommendations on the L1 processing approach, for inclusion in the operational ground segment, regarding the way antenna emission is built into the calibration equations. Also, it is shown that the nonlinear term, used for many instruments over the years, does not properly account for ageing of the receiver front-end.

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