METOP SECOND GENERATION MICROWAVE SOUNDING AND MICROWAVE IMAGING MISSIONS

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Abstract

ESA is currently running two parallel, competitive phase A/B1 studies for MetOp Second Generation (MetOp-SG). MetOp-SG is the space segment of EUMETSAT Polar System (EPS-SG) consisting of the satellites and instruments. The Phase A/B1 studies will be completed at the first quarter of 2013. The final implementation phases (B2/C/D) are planned to start in 2013.

ESA is responsible for instrument design of six missions, namely Microwave Sounding Mission (MWS), Scatterometer mission (SCA), Radio Occultation mission (RO), Microwave Imaging mission (MWI), Ice Cloud Imaging (ICI) mission, and Multi-viewing, Multi-channel, Multi-polarisation imaging mission (3MI).

This paper will present the instrument main design elements of the MWS, MWI and ICI missions.

INTRODUCTION

Microwave Sounder (MWS) is a traditional cross-track scanning microwave radiometer, providing a total number of 24 channels from 23 GHz up to 230 GHz. All measurements are performed with a single polarisation (QV or QH). MWS provides measurements of temperature and humidity profiles and total liquid water columns.

Microwave Imager (MWI) is a conically scanning microwave radiometer. All low frequency channels up to 89 GHz are measured at V and H polarisation. MWI provides measurements of cloud and precipitation products, water vapour and temperature profiles and surface imagery.

Ice Cloud Imager (ICI) is a conically scanning millimetre/sub-millimetre radiometer. It measures frequencies from 183 GHz up to 664 GHz, providing a total number of 13 channels.

MICROWAVE SOUNDER

The Microwave Sounder (MWS) provides measurements of temperature and water vapour profiles and in addition information on cloud liquid water. These are key parameters for Numerical Weather Microwave soundings, which greatly enhance the National Meteorological Services' (NMS) ability to initialise global and regional NWP models with realistic information on temperature and moisture. The frequent availability of detailed temperature and moisture soundings would also contribute to fulfil other key requirements common to Nowcasting and very short range weather forecasting at regional scales.

All MWS channels are measured with a single polarisation (QV or QH). MWS will have 40 km footprint at lowest frequencies leading to an antenna size of ~35 cm. Footprint at highest frequency channels will be 17 km. The sampling distance on ground is defined by the highest frequency channels. MWS has a non-uniform scanning profile, which maximises the scene viewing time. A quasi-optical system is used to co-locate all channels into one "main beam". All channels are required to have the same pointing within 0.1°. The MWS total scan angle will be around ± 49° with respect to nadir with a total pointing knowledge of 0.25°. The scanning pattern of MWS is shown in Figure 1.

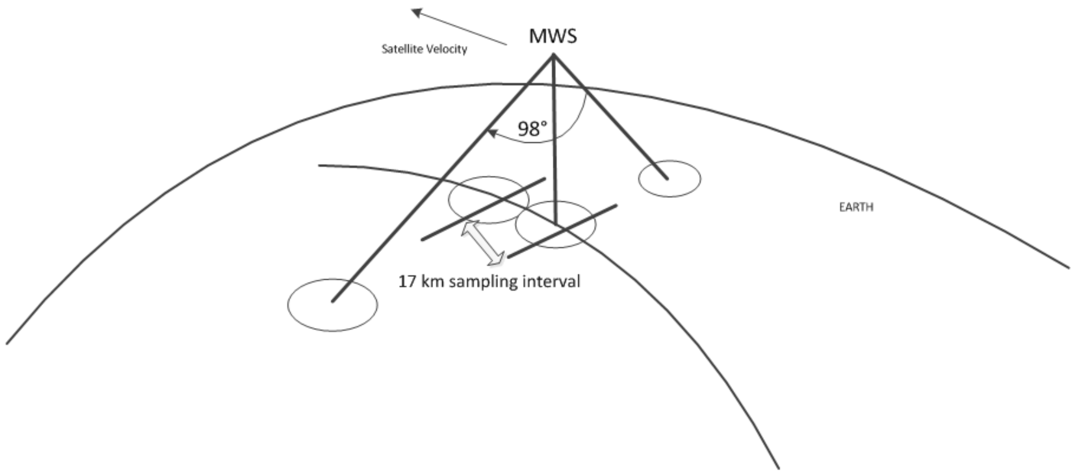

Figure 1 MWS scan angles and sampling interval

The instrument design is a single unit, single antenna concept. The large frequency range required puts a stringent requirement to the MWS quasi-optical network, which must be able to handle this frequency range. First electrical demonstrator of the quasi-optical network has been built and measured losses are typically below 0.3 dB for all channels. Table 1 below shows the predicted NEΔT values for each channel in nominal conditions, beginning of life. Predicted radiometric accuracy (RSS) is below 1K for all channels, inter-channel accuracy better than 0.5 K and inter-pixel accuracy <0.3 K (at 280K reference scene). Orbital stability better than 0.2 K is targeted. Beam efficiency is between 95% and 99% depending on channel.

Channel name	Frequency (GHz)	Utilisation	NEΔT
MWS-1	23.8	Water-vapour column	0.3
MWS-2	31.4	Window, water-vapour column	0.3
MWS-3	50.3	Quasi-window, surface emissivity	0.3
MWS-4	52.8	Temperature profile	0.3
MWS-5	53.246±0.08		0.3
MWS-6	53.596±0.115		0.3
MWS-7	53.948±0.081		0.3
MWS-8	54.4		0.3
MWS-9	54.94		0.3
MWS-10	55.5		0.3
MWS-11	57.290344		0.35
MWS-12	57.290344±0.217		0.5
MWS-13	57.290344 ±0.3222±0.048		0.5
MWS-14	57.290344±0.3222±0.022		0.8
MWS-15	57.290344±0.3222±0.010		1.1
MWS-16	57.290344±0.3222±0.0045		1.8
MWS-17	89	Window	0.2
MWS-18	165.5±0.725	Quasi-window, water-vapour profile	0.4
MWS-19	183.311±7.0	Water-vapour profile, precipitation	0.35
MWS-20	183.311±4.5	Water-vapour profile	0.35
MWS-21	183.311±3.0		0.5
MWS-22	183.311±1.8		0.5
MWS-23	183.311±1.0		0.7
MWS-24	229	Quasi-window water-vapour profile	0.5

Table 1 MWS Channels, utilisation and predicted NEΔT

MICROWAVE IMAGER

The MicroWave Imager is a conically scanning microwave radiometer, providing a total number of 26 channels (including dual polarisation channels). MWI frequency coverage is from 18 GHz up to 183 GHz. Table 2 shows the MWI channels, utilisation purpose and NEΔT. All MWI channels up to 89 GHz are measured with both V- and H polarisations. Channels above 89 GHz are measured at V polarisation only.

Channel name	Frequency (GHz)	Utilisation	NEΔT [K]
MWI-1	18.7	Precipitation over sea	0.7
MWI-2	23.8	Total column water vapour over sea	0.6
MWI-3	31.4	Precipitation over sea and (marginally) land	0.8
MWI-4	50.3	Precipitation over sea and land including drizzle, snowfall, height and depth of the melting layer	0.7
MWI-5	52.61		0.7
MWI-6	53.24		0.7
MWI-7	53.75		0.7
MWI-8	89	Precipitation (sea & land) & snowfall	0.8
MWI-9	118.7503±3.2	Precipitation over sea and land including light precipitation and snowfall, height and depth of the melting layer	1.2
MWI-10	118.7503±2.1		1.2
MWI-11	118.7503±1.4		1.2
MWI-12	118.7503±1.2		1.2
MWI-13	165.5±0.725	Quasi-window, water-vapour profile, precipitation over land, snowfall	1.1
MWI-14	183.31±7.0	Water vapour profile and snowfall	1.0
MWI-15	183.31±6.1		1.1
MWI-16	183.31±4.9		1.1
MWI-17	183.31±3.4		1.1
MWI-18	183.31±2.0		1.2

Table 2 MWI channels, utilisation and predicted NEΔT

The main objective of the MWI is to measure precipitation. In addition, MWI provides measurements of cloud products, water vapour and temperature profiles and surface imagery. MWI supports Numerical Weather Prediction at regional and global scales. MWI has a moderate antenna size providing on-ground footprints ranging from 50 km down to 10 km, depending on frequency.

As mentioned above, the MWI has a relatively small antenna size (~75 cm) leading to 50 km footprints at lowest frequencies. On the other hand, the small antenna does not require deployment mechanism and enables a complete sun shield around the instrument to protect from sun-intrusions. On board calibration target and cold sky reflector are viewed once every rotation cycle. MWI will provide azimuth viewing scan angles greater than 65°. The observation zenith angle (OZA) will be around 53°, depending on channel and will be constant within 1°. Smallest antenna footprint defines the minimum rotation cycle, and footprint overlap is present also for highest frequencies due to the high rotation rate (45 RPM). This guarantees a good image quality and even Nyquist spatial sampling at the lowest frequency channels.

Additional features of MWI include Radio Frequency Interference (RFI) mitigation at the lowest frequency channel and internal calibration targets to complement traditional external targets. RFI mitigation is done by dividing the measured signal spatially, spectrally and temporally and detecting non-gaussian (man-made) signals and removing them from the data. Internal calibration targets will be implemented at the lowest frequency channels, providing improvement of orbital stability of the instrument.

ICE CLOUD IMAGER

The Ice Cloud Imager (ICI) is a conically scanning millimetre/sub-millimetre wave radiometer, providing a total number of 13 channels (including dual polarisation channels). The ICI frequency coverage is from 183 GHz up to 664 GHz, with two window channels (243 GHz and 664 GHz) measured at both V and H polarisation. Table 3 shows the ICI channels and utilisation. Contrary to traditional conical scanners, ICI will be mounted on nadir side of the spacecraft. 183 GHz channel selection overlaps with the one of MWI, allowing a cross-calibration between the instruments.

ICI has a small antenna size providing 15 km on-ground footprints at all frequencies. Fast rotation speed (45 RPM) will provide Nyquist spatial sampling for all channels.

Complementarily to MWI instrument, ICI will measure primarily ice clouds, especially cirrus clouds, cloud ice water path, cloud ice effective radius and cloud altitude. In addition, ICI will provide vertical humidity profile and vertical profiles of hydrometeors (cloud ice, graupel, snow, rain and cloud liquid), as well as total column precipitation rate and water vapour. As for MWI, specific efforts have been put into designing ICI hot calibration target with the exception of internal calibration targets, which are not planned for ICI. For what concerns footprints overlap and image quality, similar considerations done for MWI have been also applied to ICI.

The ICI channels, utilisation and predicted NEΔT is given in table 3 below.

Channel name	**Frequency (GHz)**	**Utilisation**	**NEΔT [K]**
ICI-1	183.31±7.0	Water vapour profile and snowfall	0.6
ICI-2	183.31±3.4		0.7
ICI-3	183.31±2.0		0.7
ICI-4	243.2±2.5	Quasi-window, cloud ice retrieval, cirrus clouds	0.6
ICI-5	325.15±9.5	Cloud ice effective radius	1.1
ICI-6	325.15±3.5		1.2
ICI-7	325.15±1.5		1.4
ICI-8	448±7.2	Cloud ice water path and cirrus	1.3
ICI-9	448±3.0		1.5
ICI-10	448±1.4		1.9
ICI-11	664±4.2	Cirrus clouds, cloud ice water path	1.5

Table 3 ICI channels, utilisation and NEΔT

CONCLUSIONS

The Microwave Sounder (MWS), Microwave Imager (MWI) and Ice Cloud Imager (ICI) missions will form part of the MetOp-SG programme being implemented in collaboration with EUMETSAT and targeting an operational system of 21 years of operations. This paper has presented the main performance and design characteristics of the associated instruments as currently defined within the on-going Phase A/B1 feasibility studies.

REFERENCES

[1]. Post-EPS Mission Requirements Document, EUM/PEPS/REQ/06/0043, v3C, 25 June 2010, available at http://www.eumetsat.int/groups/pps/documents/document/pdf_peps_mrd.pdf