INTERNATIONAL PRECIPITATION WORKING GROUP (IPWG)

REQUIREMENTS OF IPWG FOR MW/SUB-MM FREQUENCIES PROTECTION

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1. Purpose of document

At the 1st Workshop of the CGMS/WMO International Precipitation Working Group (Madrid, 23-27 September 2002) the interest of using millimetre and sub-millimetre waves for frequent rain observation from geostationary satellites was recognised. The issue of frequency protection of the appropriate atmospheric windows and O_2 and H_2O absorption bands was identified. It was noted that the CGMS/WMO International TOVS Working Group (ITWG) has now a status in the ITU competent bodies. Therefore, it was decided to officially transfer requirements from IPWG to ITWG through CGMS. The action to prepare a document to serve that purpose was placed on B. Bizzarri. This short note is the response to that action.

2. Background

The principle of precipitation measurement from geostationary orbit is based on the use of absorption bands of O_2 for atmospheric temperature profiling and H_2O for water vapour profiling. Profiles retrieved by bands at different frequencies are differently affected by liquid water, ice water, drop size and shape, and hence precipitation. The American project GEM (Geostationary Microwave observatory) and the European one GOMAS (Geostationary Observatory for Microwave Atmospheric Sounding), actually closely linked to each other, have determined the need for the set of bands and channels shown in ***Table 1***.

Table 1 – Bands and channels defined for rain observation through temperature/humidity sounding
(from the GEM and GOMAS projects – detailed specifications still subject to adjustments)

54 GHz		118 GHz		183 GHz		380 GHz		425 GHz	
ν (GHz)	Δν (MHz)	ν (GHz)	Δν (MHz)	ν (GHz)	Δν (MHz)	ν (GHz)	Δν (MHz)	ν (GHz)	Δν (MHz)
56.325	50	118.7503 ± 0.018	6	183.3101 ± 0.300	300	380.1974 ± 0.045	30	424.7631 ± 0.030	10
56.215	50	118.7503 ± 0.035	12	183.3101 ± 0.900	500	380.1974 ± 0.400	200	424.7631 ± 0.070	20
56.025	250	118.7503 ± 0.080	20	183.3101 ± 1.650	700	380.1974 ± 1.500	500	424.7631 ± 0.150	60
55.520	180	118.7503 ± 0.200	100	183.3101 ± 3.000	1000	380.1974 ± 4.000	900	424.7631 ± 0.300	100
54.950	300	118.7503 ± 0.400	200	183.3101 ± 5.000	2000	380.1974 ± 9.000	2000	424.7631 ± 0.600	200
54.400	220	118.7503 ± 0.700	400	183.3101 ± 7.000	2000	380.1974 ± 18.000	2000	424.7631 ± 1.000	400
53.845	190	118.7503 ± 1.100	400	183.3101 ± 17.000	4000	340.0	8000	424.7631 ± 1.500	600
53.290	360	118.7503 ± 1.500	400			optional/auxiliary		424.7631 ± 4.000	1000
52.825	300	118.7503 ± 2.100	800						
51.760	400	118.7503 ± 3.000	1000						
50.300	180	118.7503 ± 5.000	2000						

The Signal-to-Noise Ratio (SNR) requirement for temperature/humidity sounding is: SNR > 100, corresponding, for different channels, to Noise Equivalent Difference Temperature (NEΔT) ranging from 0.1 to 0.6 K.

In addition to these requirements, it is appropriate to consider the requirements put forward for ***cloud ice*** observation. This is based on using sub-millimetre waves in atmospheric windows, associated to a few channels in H_2O to set the background (the Earth surface is masked at these frequencies because of the water vapour continuum). The appropriate frequencies have been defined in the context of the project CIWSIR (Cloud Ice and Water-vapour Sub-mm Imaging Radiometer), and are reported in ***Table 2***.

There are two versions of this project, one limited to cirrus cloud observation, another that adds the capability of temperature/humidity profiling in the Upper Troposphere / Lower Stratosphere (UT/LS) by two sub-millimetre absorption bands identical to the 380 GHz H_2O and 425 GHz O_2 bands of GEM/GOMAS.

Table 2 – Bands and channels defined for cloud ice observation and UT/LS temperature/humidity sounding
(from the CIWSIR project extended to a UT/LS mission – Note that this is a mission for LEO)

"Cirrus" channels				"Sounding" channels			
ν (GHz)	Δν (MHz)	NEΔT (K)	Polarisation	ν (GHz)	Δν (MHz)	NEΔT (K)	Polarisation
874.38 ± 6.00	3000	1.5	two	424.7631 ± 0.030	10	0.5	one
682.95 ± 6.00	3000	1.0	two	424.7631 ± 0.070	20	0.6	
448.00 ± 1.44	1560	1.0	one	424.7631 ± 0.150	60	0.6	
448.00 ± 3.00	1560	1.0		424.7631 ± 0.300	100	0.5	
448.00 ± 7.20	3000	1.0		424.7631 ± 0.600	200	0.5	
325.15 ± 1.50	1680	1.0	one	424.7631 ± 1.000	400	0.5	
325.15 ± 3.18	1680	1.0		424.7631 ± 1.500	600	0.5	
325.15 ± 5.94	3000	1.0		424.7631 ± 4.000	1000	0.4	
183.31 ± 1.47	1380	1.0	one	380.1974 ± 0.045	30	0.3	one
183.31 ± 2.85	1380	1.0		380.1974 ± 0.400	200	0.5	
183.31 ± 4.50	1920	1.0		380.1974 ± 1.500	500	0.5	
				380.1974 ± 4.000	900	0.5	
				380.1974 ± 9.000	2000	0.4	
				380.1974 ± 18.000	2000	0.3	

The frequencies used for precipitation observation in the MW range from LEO have already been the subject of protection requirement. However, for completeness, we provide in ***Table 3*** the list of requirements for the MW radiometer of EGPM (European contribution to the Global Precipitation Mission). It is noted that EGPM is considering the option to add O_2 absorption bands (54 and 118 GHz) for improved precipitation observation over land including light rain and snowfall.

Table 3 – Bands and channels defined for precipitation observation from LEO
(from the EGPM project – Baseline channels are shadowed. The other ones are optional channels)

"Classical" channels for precipitation				Sounding channels for improved observation over land including light rain and snowfall							
ν (GHz)	Δν (MHz)	NEΔT (K)	Polarisation	ν (GHz)	Δν (MHz)	NEΔT (K)	Polarisation	ν (GHz)	Δν (MHz)	NEΔT (K)	Polarisation
157.0 (*)	3000	1.0	two	56.025	250	0.5	one	118.7503 ± 0.200	100	0.5	one
89.0	3000	1.0		55.520	180	0.4		118.7503 ± 0.400	200	0.5	
36.5	1000	0.7		54.950	300	0.4		118.7503 ± 0.700	400	0.5	
23.8	400	0.6		54.400	220	0.3		118.7503 ± 1.100	400	0.4	
18.7	200	0.5		53.845	190	0.3		118.7503 ± 1.500	400	0.4	
10.7	100	0.4		53.290	360	0.3		118.7503 ± 2.100	800	0.3	
(*) Alternative: 150.0 GHz				52.825	300	0.2		118.7503 ± 3.000	1000	0.2	
				51.760	400	0.1		118.7503 ± 5.000	2000	0.1	
				50.300	180	0.1					

3. Envelop of requirements

The envelop of all requirements for precipitation observation (including the implied temperature and humidity sounding) and connected cloud ice observation is summarised in ***Table 4***. The frequency range has been defined with a margin of half-bandwidth on each side of the channel or the band. The level of protection has been defined about one-order-of magnitude lower than NEΔT, finally rounded to 0.05 K for atmospheric windows and H_2O bands, and 0.01 K for O_2 bands. It is realised that frequencies below 240 GHz have already been regulated; however, they are mentioned for the sake of completeness. For comfort, the first four columns of Table 4 report the reference data from Tables 1, 2 and 3.

Table 4 – IPWG requirements for frequencies protection

Input data for the requirements				Final requirements			
Reference channel (GHz)	**Bandwidth (GHz)**	**NEΔT (K)**	**Reference Table**	**Frequency range (GHz)**	**Level of protection NEΔT (K)**	**Nature of the band**	**Usage**
10.7	0.1	0.4	Table 3	10.6-10.8	0.05	Atmospheric window	Precipitation over sea
18.7	0.2	0.5	Table 3	18.5-18.9	0.05	Atmospheric window	Precipitation over sea
23.8	0.4	0.6	Table 3	23.4-24.2	0.05	H_2O absorption band	Precipitation over sea Total-column water vapour over sea
36.5	1.0	0.7	Table 3	35.5-37.5	0.05	Atmospheric window	Precipitation over sea and marginally over land
From 50.300 to 56.025	0.180 0.250	0.1 0.5	Tables 1 and 3	50.0-57.0	0.01	O_2 absorption band	Precipitation over sea and land Temperature profile through the entire troposphere
89.0	3.0	1.0	Table 3	86.0-92.0	0.05	Atmospheric window	Precipitation over sea and land
118.75 ± 5.00	2.0	0.1	Tables 1 and 3	110-126	0.01	O_2 absorption band	Precipitation over sea and land including light rain and snowfall Temperature profile through the entire troposphere
Either 150.0 or 157.0	3.0	1.0	Table 3	147-160	0.05	Atmospheric window	Precipitation over sea and land including light rain and snowfall
183.31 ± 17.00	4.0	0.3	Table 1 driving (also Table 2)	162-204	0.05	H_2O absorption band	Precipitation over sea and land including light rain and snowfall Humidity profile through the entire troposphere Background for cloud ice observation
325.15 ± 5.94	3.0	1.0	Table 2	316-334	0.05	H_2O absorption band	Background for cloud ice observation
340.0	8.0	1.0	Table 1	332-348	0.05	Atmospheric window	Precipitation over sea and land including light rain and snowfall
380.2 ± 18.0	2.0	0.3	Tables 1 and 2	360-400	0.05	H_2O absorption band	Precipitation over sea and land including light rain and snowfall Humidity profile in upper troposphere / lower stratosphere
424.76 ± 4.00	1.0	0.4	Tables 1 and 2	420-430	0.01	O_2 absorption band	Precipitation over sea and land including light rain and snowfall Temperature profile in upper troposphere / lower stratosphere
448.0 ± 7.2	3.0	1.0	Table 2	438-458	0.05	H_2O absorption band	Background for cloud ice observation
682.95 ± 6.00	3.0	1.0	Table 2	674-692	0.05	Atmospheric window	Cloud ice observation
874.38 ± 6.00	3.0	1.5	Table 2	865-883	0.05	Atmospheric window	Cloud ice observation