Channel Selection and Analysis of Geostationary Interferometric sub-millimeter Sounder

HE Jieying, ZHANG Shengwei

（Key Laboratory of Microwave Remote Sensing, Center for Space Science and Applied Research, Chinese Academy of Sciences, Beijing 100190, China）

Email: hejieying@mirslab.cn

Abstract:

Geostationary sub-millimeter atmospheric sounder based on interferometric technology is the newest field of microwave remote sensing. Equipped with a sub-millimeter atmospheric remote sensing instruments on the geostationary orbit meteorological satellite platform will increase the frequency of observations at the same time, improve the cloud detection capability. The current polar-orbiting meteorological satellite observation system ensures that only six hours of observation period, unable to typhoons and other fast-changing weather systems for real-time observation. Geostationary sub-millimeter sounder [1-3] has the characteristics of working all-weather, all-time, large coverage and real-time. The whole process of dynamic changes in the weather can be observed, providing high temporal resolution observation data for numerical weather prediction and immediate short-term forecasting. In the paper, the content will mainly include channel Selection and analysis of geostationary interferometric sub-millimeter sounder.

Keywords: Atmospheric parameters, geostationary sub-millimeter sounder, interferometric technology, channel Selection

1. Introduction

Atmospheric parameters such as atmospheric temperature and humidity sounded by microwave radiometer are necessary to improve numerical weather prediction and climate change research. Geostationary sub-millimeter sounder [1-3] has the characteristics of working all-weather, all-time, large coverage and real-time. The whole process of dynamic changes in the weather can be observed, providing high temporal resolution observation data for numerical weather prediction and immediate short-term forecasting, even forecast can be realized in changing humidity field, thermal field, small and medium-scale disasters such as heavy rains and strong convective weather phenomenon, process development and disappearance. Geostationary microwave atmospheric sounder based on interferometric technology is the newest field of microwave remote sensing [4-5].

The geostationary orbit meteorological satellite can cover the whole area of the disc, covering the eastern Pacific, the South China Sea, the Indian Ocean and other hot spots.

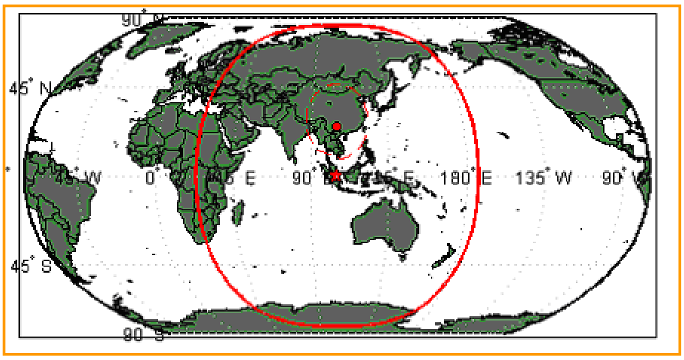


Fig.1 geostationary orbit meteorological satellite observing region

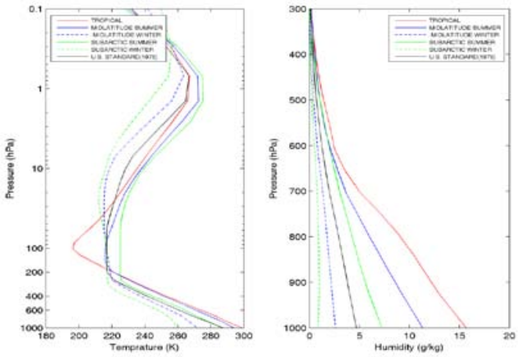
2. Datasets for simulation

National Centers for Environmental Prediction (NCEP) Global Data Assimilation System (GDAS) is generated every 6 hours using a Medium Range Forecast model (MRF) and consists of the minimum set necessary to regenerate NCEP analysis fields, which is the basis of the simulation model.

In this paper, the standard atmospheric profiles are used, which are shown in figure 2. Based on

978-1-4673-5225-3/14/$31.00 ©2014 IEEE

these typical profiles, the gasous absorption coefficients from 0~1000GHz shown in figure3. Candidate frequencies for geostationary sub-millimeter sounder are list in table 1, which provides the sounding characteristics of oxygen and water vapor absorbing lines.



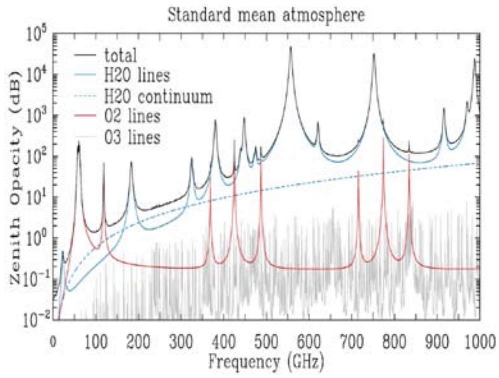


Fig. 2 The standard atmospheric profiles

Fig. 3 The gasous absorption coefficients from 0~1000GHz

Table 1 Candidate frequencies for geostationary sub-millimeter sounder

No.	Frequency（GHz）	characteristics	Applications
1	55-64	Oxygen	Temperature profiles
2	118.75	Oxygen	Temperature profiles
3	150.0	window	Surface information
4	183.31	Water vapor	Humidity profiles
5	220.0	window	Surface information
6	380.19	Water vapor	Humidity profiles
7	424.76	Oxygen	Temperature profiles
8	556.93	Water vapor	Humidity profiles

3. Atmospheric temperature and humidity sounding principle

Since atmospheric absorbing characteristics of water vapor and oxygen, using satellite-borne microwave radiometer to derive atmospheric temperature and humidity profiles is possible [6]. According to the principle above, when the radiometer operated at frequencies 50～1000GHz, the contribution of surface background noise can be reduced to negligible magnitude, because the transmittance of the atmosphere at these frequencies is approximately equal to 0.

Atmospheric opacity thickness with pressure integration can be expressed as:

$$\tau(z)=\int_0^z \alpha(z')dz' \tag{1}$$

Where $\alpha(z)$ is atmospheric at altitude z, z' is height from surface to satellite.

For oxygen absorbing channels， $\tau(z)$ is basically due to the contribution of oxygen.

Equation (1) can be expressed as the weighted integral of temperature:

$$T_b(v,\theta)=T_u(v,\theta)+\int_0^\infty W_T(v,\theta,z)T(z)\sec(\theta)dz \tag{2}$$

The temperature weighing function can be expressed as:

$$W_T(v,\theta,z)=\left[1+(1-e_s)\left(\frac{\Upsilon_{v\theta}(0,\infty)}{\Upsilon_{v\theta}(z,\infty)}\right)^2\right]\frac{\partial\Upsilon_{v\theta}(z,\infty)}{\partial z} \tag{3}$$

Where, $$\gamma_{v,\theta}(0,\infty) = e^{-\tau(0)\sec(\theta)} \tag{4}$$

Furthermore, water vapor weighing function can be expressed as:

$$W_\rho(v,z) = W_T(v,z)\frac{T(z)}{\rho_v(z)} \tag{5}$$

Weighting function is the weight of atmospheric radiance at height z from surface to the height of the satellite. The plane parallel atmosphere was divided into N layers, the absorbing coefficient of atmospheric parameters was assumed uniform in each layer, and then attenuation contributions of entire atmosphere including the surface layer can be accumulated. Atmospheric absorbing coefficients in each channel can be calculated combining MPM93[7] and PWR04[8] model.

4. Channel selection and analysis

According to the atmospheric sounding theory and gasous absorption coefficients from 0~1000GHz, the final frequencies are chosen to derive atmospheric temperature and humidity profiles for geostationary sub-millimeter sounder, which are list in figure 4 and table 2.

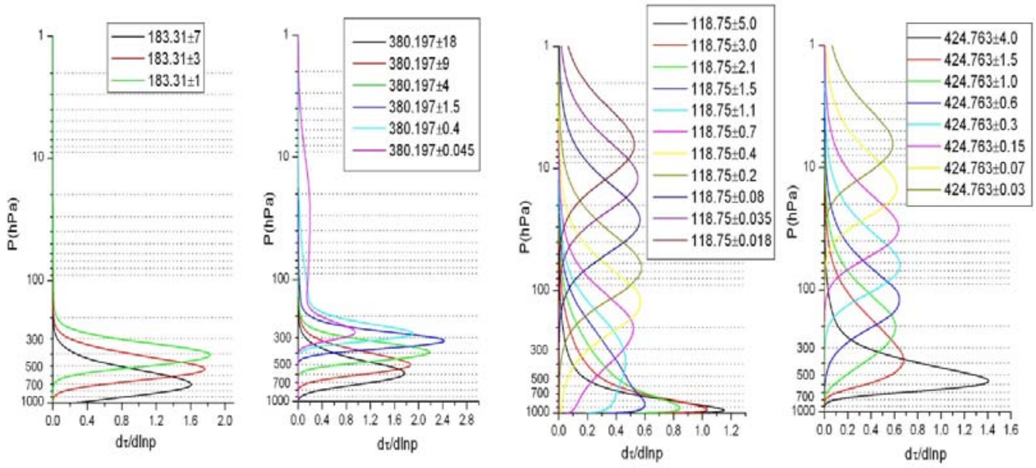


Fig.4 weighting functions for candidate frequencies

Table 2 Frequencies for geostationary sub-millimeter sounder

Atmospheric temperature sounding				Atmospheric humidity sounding	
Frequency（GHz）	bandwidth（MHz）	Frequency（GHz）	bandwidth（MHz）	Frequency（GHz）	bandwidth（MHz）
52.2~52.5	300	118.75±5.0	2000	183.31±7.0	2000
53.15～53.4	250	118.75±3.0	1000	183.31±5.0	1000
53.65～53.95	300	118.75±2.1	800	183.31±4.0	500
54.3~54.5	250	118.75±1.5	400	183.31±2.0	1000
54.75～54.95	200	118.75±1.1	400	183.31±1.0	500
56.1～56.2	100	118.75±0.7	400		
		118.75±0.4	200	380.197±18.0	3000
		424.763±4.0	2000	380.197±9.0	2000
		424.763±1.5	600	380.197±4.0	900
		424.763±1.0	400	380.197±1.5	500
		424.763±0.6	200	380.197±0.4	200

		424.763±0.3	100		
		424.763±0.15	60		
		424.763±0.07	20		
		424.763±0.03	10		

Compared to the relatively mature technology of 50 ~ 70GHz, adopting 118.75GHz and higher frequencies can avoid using large antenna and can further improve the spatial resolution. For antennas in the same size, the view pixels of 118.75GHz channels are approximately half of them compared to 60GHz channels. The analysis is made to determine the optimal combinations of frequency and bandwidth. The channels near 118.75GHz include more information about cloud and water vapor compared to 60GHz.

5. Conclusions

Geostationary sub-millimeter sounder has the characteristics of working all-weather, all-time, large coverage and real-time. The whole process of dynamic changes in the weather can be observed, providing high temporal resolution observation data for numerical weather prediction and immediate short-term forecasting. The paper discusses the channels selection, including analysis the frequency and bandwidth. Therefore, it will play an important role for design and developing the new generational geostationary microwave/sub-millimeter sounder.

References:

[1] STAELIN D, GASIEWSKI A, KEREKES J, et al. Concept proposal for a Geostationary Microwave (GEM) Observatory [J]. Prepared for the NASA/NOAA Advanced Geostationary Sensor (AGS) Program, 1998, 23.

[2] BIZZARI B. GOMAS-Geostationary Observatory for Microwave Atmospheric Sounding [J]. submitted to ESA in response to the call for ideas for the Next Earth Explorer Core Missions, 2005,

[3] A.B. Tanner, W.J. Wilson, B.H. Lambrigsten, S.J. Dinardo, S.T. Brown, P.P. Kangaslahti, T.C. Gaier, C.S. Ruf, S.M. Gross, B.H. Lim, S.B. Musko, S. Rogacki, J.R. Piepmeier, "Initial Results of the Geostationary Synthetic Thinned Array Radiometer (GeoSTAR) Demonstrator Instrument", IEEE Trans. on GRS, Volum 45, Issue 7, Jul., 2007.

[4] LIU H, WU J, ZHANG S, et al. Conceptual design and breadboarding activities of Geostationary Interferometric Microwave Sounder (GIMS); proceedings of the Geoscience and Remote Sensing Symposium,2009 IEEE International,IGARSS 2009, F 12-17 July 2009 [C].

[5] LIU H, WU J, ZHANG S, et al. The geostationary interferometric microwave sounder (GIMS): instrument overview and recent progress; proceedings of the Geoscience and Remote Sensing Symposium (IGARSS), 2011 IEEE International, F 24-29 July 2011 [C].

[6] BIZZARRI B, MUGNAI A, PINORI S. Temperature and humidity sounding from GEO by millimetre-submillimetre wave radiometry, Extracted from the Final Report of study contract EUM/CO/04/1386/KJG: "Simulations and User Requirements Review for Precipitating Clouds from Geostationary Orbits in Mm/Sub-mm Bands (GeoRain)"

[7] H. J. Liebe, "MPM -- An atmospheric millimeter-wave propagation model," International Journal of Infrared and Millimeter Waves 1989; 10 (6): 631-650.

[8] P W. Rosenkeanz, "Retrieval of temperature and moisture profiles from AMSU-A and AMSU-B measurements," IEEE transactions on geosciences and remote sensing, 2001, 39(11):2429-2435.