SHARING STUDIES BETWEEN SPACEBORNE PASSIVE MICROWAVE RADIOMETER AND OTHER SERVICES

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ABSTRACT

MSR (Microwave Scanning Radiometer) mounted on MOS-1(Marine Observation Satellite-1) and MOS-1b were launched on Feb.19, 1987 and Feb.7, 1990. Moreover, AMSR-E (Advanced Microwave Scanning Radiometer for Earth Observing System) mounted on AQUA and AMSR mounted on ADEOS-II (Advanced Earth Observing Satellite -II) were launched on May 4 and December, 2002, respectively. These radiometers have been developed by NASDA (now JAXA). In the latter radiometer, more advanced performance is realized than the former radiometers due to higher beam efficiency and better spatial resolution with 8 channels (AMSR), 6 channels (AMSR-E) and larger aperture (diameter 1600mm (AMSR-E) and 1950mm (AMSR)). As a result of testing in the orbit and verification comparing with truth data, these performances were verified and it was found that extraction accuracy of various physical parameter related with global water circulation almost meets specifications. However, it has been found that imagery is contaminated by interference in some MSR/MSR-E pixels in some channels.

In order to protect spaceborne passive microwave radiometer such as AMSR and AMSR-E, it is necessary to conduct compatibility analysis between passive microwave radiometer and other services in 10GHz , 36GHz and other bands. For that, firstly, new reference antenna pattern was proposed and compared with measured antenna pattern. Secondly, world deployment model was newly proposed and used which is a function of population of each city. Thirdly, some results of sharing studies with point-to-point fixed service stations have been shown and it was found that beam efficiency and sidelobe level of antenna pattern has much impact on results. Finally, higher beam efficiency with lower sidelobe which leads to higher performance of observation provides smaller interference time percentage. Therefore, very high beam efficiency of antenna of spaceborne microwave radiometer is the design target for future spaceborne microwave radiometer in order to mitigate interference from other services.

INTRODUCTION

NASDA (now JAXA) conducted airborne experiment [1] using EM (Engineering Model) of microwave radiometer before the launch of MSR (Microwave Scanning Radiometer) (23.8GHz and 31.4GHz bands, diameter 50cm) mounted on MOS-1 (Marine Observation Satellite-1) and during flight of MOS-1. MSR mounted on MOS-1 and MOS-1b were launched on Feb.19, 1987 and Feb.7, 1990, respectively. [2] AMSR (Advanced Microwave Scanning Radiometer) mounted on ADEOS-II and AMSR-E (Advanced Microwave Scanning Radiometer for Earth Observing System) mounted on AQUA were launched on Dec.14, 2002 and May 4, 2002, respectively. [3],[4] In the case of MSR, bias error in deriving geophysical parameter such as water vapor was recognized due to insufficient beam efficiency. At that time, higher spatial resolution was required rather than higher beam efficiency. Based upon evaluation results of MOS-1 MSR data, higher beam efficiency for AMSR and AMSR-E were strongly required. It is found in the simulation that AMSR data with lower sidelobe level of antenna pattern is not so influenced by radio interference. However, in order to protect spaceborne microwave radiometer, it is necessary to evaluate impact from interference of other services. [5] In this paper, results of evaluation in 10.6-10.68GHz as an example are presented by using simulation with newly proposed reference antenna pattern.

DERIVED GEOPHYSICAL PARAMETER AND STATUS OF ALLOCATION

AMSR and AMSR-E has 6 channels (6.9GHz, 10.6GHz, 18.7 GHz, 23.8 GHz, 36.5GHz and 89.0GHz bands) to produce seven kinds of the geophysical parameters (water vapor, cloud liquid water, precipitation, sea surface wind speed, sea surface temperature, snow depth, sea ice concentration). AMSR has more two channels (50.3GHz, 52.8GHz bands) to measure temperature of lower atmosphere. These geophysical parameters are produced by combining several channels. Therefore, it is necessary to protect all channels from the interference of other services. Protection criteria of passive microwave radiometer are specified by Rec.ITU-R SA.1029-2 (Interference criteria for satellite passive remote sensing). Concerning 6.9 GHz band, the use of passive microwave radiometer is indicated by ITU-R Radio Regulations (R.R.)

No.5.458 and not allocated. Concerning 10.6-10.68GHz, sharing criteria with fixed and mobile services is shown in R.R. No.5.482 which may be insufficient to protect passive sensors and such conditions are not applicable in 27 countries in the world. Concerning 23.6-24 GHz band, there may be much impact from UWB automobile collision avoidance radar. It is found that AMSR and AMSR-E data are contaminated due to interference in various regions. Much effort is needed to protect such sensors in various meetings such as SFCG (Space Frequency Coordination Group), CEOS (Committee on the Earth Observation Satellites), ITU-R and meeting of the Group on the Earth Observations (GEO) produced by Earth Observation Summit.

EXAMPLES OF SHARING STUDIES

Using Diameter D, wavelength λ, maximum of antenna gain G_{max} and aperture efficiency η of microwave radiometer, the following modified reference antenna pattern is derived from measurement data for AMSR and AMSR-E.

$\frac{D}{\lambda} > 100$

$$G(\varphi) = G_{max} - 1.49 \times 10^{-3} \left(\frac{D}{\lambda}\varphi\right)^2 \qquad \text{for} \quad 0° < \varphi \le \varphi_m$$

$$G(\varphi) = \max\left(G_{max} - 1.49 \times 10^{-3} \left(\frac{D}{\lambda}\varphi\right)^2, 23 - 25\log(\varphi)\right) \qquad \text{for} \quad \varphi_m < \varphi \le 69.183°$$

$$G(\varphi) = -23 \qquad \text{for} \quad 69.183° < \varphi$$

Where:

$$G_{max} = 10\log\left(\eta\pi^2 \frac{D^2}{\lambda^2}\right)$$

$$G_1 = 4.5 + 15\log\left(\frac{D}{\lambda}\right)$$

$$\varphi_m = \frac{10\lambda}{D}\sqrt{G_{max} - G_1}$$

$\frac{D}{\lambda} \leqq 100$

$$G(\varphi) = G_{max} - 1.49 \times 10^{-3} \left(\frac{D}{\lambda}\varphi\right)^2 \qquad \text{for} \quad 0° < \varphi \le \varphi_m$$

$$G(\varphi) = \max\left(G_{max} - 1.49 \times 10^{-3} \left(\frac{D}{\lambda}\varphi\right)^2, 33.56 - 5\log\left(\frac{D}{\lambda}\right) - 25\log(\varphi)\right)$$

$$\text{for} \quad \varphi_m < \varphi \le 69.183°$$

$$G(\varphi) = -13.44 - 5\log\left(\frac{D}{\lambda}\right) \qquad \text{for} \quad 69.183° < \varphi$$

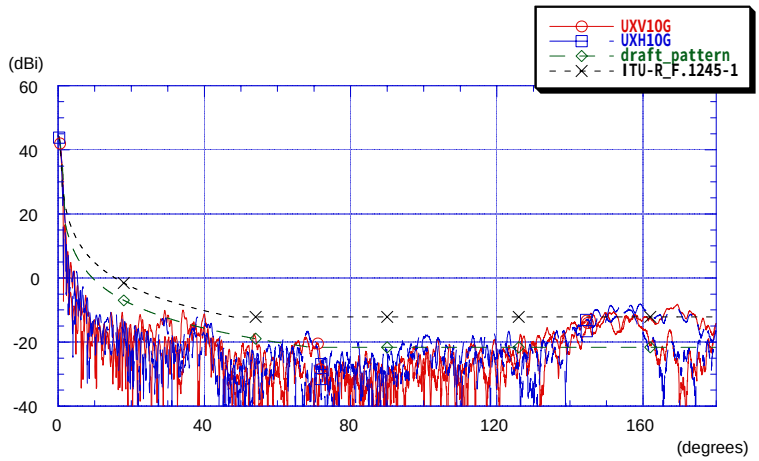

Fig. 1 Antenna pattern for AMSR in 10.6-10.68GHz

If η=0.6 is used, $$20\log\left(\frac{D}{\lambda}\right) = G_{\max} - 7.7$$

Reference antenna pattern for 10.6-10.68GHz is shown in Fig. 1 where measurement data and antenna pattern specified by Rec.ITU-R F.1245-1 developed for fixed service satations are also indicated. Assumptions of parameters for fixed service station and earth observation satellite are shown in Table 1 and Table 2. Protection criteria is interference time percentage of 0.1% exceeding -156dBW/100MHz, -166 dBW/100 MHz (sensors in next 5-10 years). CDF (cumulative distribution function) curves were calculated for 431 cities in the world where 4 ~108 stations for each city was used based upon deployment model according to population of the city.

Table 1. Parameters of point-to- point fixed station

Parameter	Characteristics
Transmitter power	-3 dBW
Antenna Gain	51 dBi
Elevation angle	0~ 5 °
Antenna pattern	Rec. ITU-R F.1245-1

Table 2. Parameters of earth observation satellite

Parameter	Characteristics
Altitude	802.92 km
Inclination	98.2 °
Antenna pattern	Rec. ITU-R S.672-4 and proposed reference antenna draft pattern based upon measurement data
Antenna gain	44.4 dBi
Axis ratio	1.0
Off-nadir angle	46.7 °

RESULTS OF SIMULATION

Table 3 and 4 show results of interference time percentage obtained from calculated CDF for AMSR data. Some result of CDF using proposed antenna pattern is shown in Fig. 2. It was found that antenna pattern specified by Rec. ITU-R S.672-4 provides higher interference percentage than proposed reference antenna pattern based upon measurement data. Antenna pattern specified by Rec. ITU-R S.672-4 has been developed for Fixed Satellite Service and if this antenna pattern is used for spaceborne microwave radiometer, sidelobe level is higher than proposed reference antenna pattern and interference is overestimated. It is recognized that lower sidelobe level leads to smaller interference percentage. Therefore, higher beam efficiency which means lower sidelobe level should be design target of future spaceborne microwave radiometer. It is also found from Table 3 and 4 that spaceborne microwave radiometer suffers from more interference over the land area than over ocean area.

Table 3. Interference percentage for 10.6-10.68GHz in the use of antenna pattern (ITU-R S.672-4)

Protection criteria	Total	Land	Ocean
-156dBW/100MHz	23.7%	37.9%	17.0%
-166dBW/100MHz	51.3%	66.4%	44.2%

Table 4. Interference percentage for 10.6-10.68GHz in the use of proposed reference antenna pattern

Protection criteria	Total	Land	Ocean
-156dBW/100MHz	4.67%	8.27%	2.96%
-166dBW/100MHz	18.51%	29.69%	13.28%

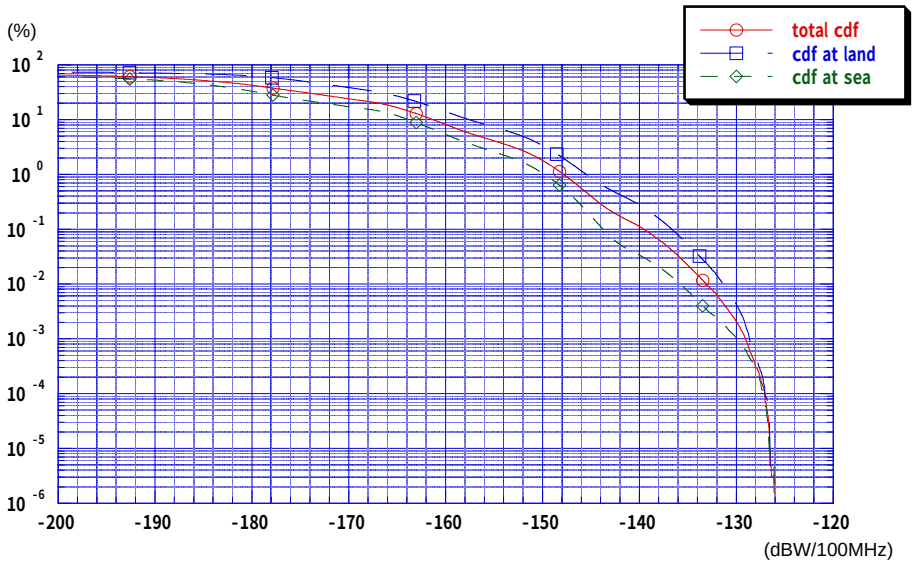

Fig. 2 CDF curve using proposed reference antenna pattern (10.6-10.68GHz)

CONCLUSION

Based upon measurement data of AMSR and AMSR-E, modified reference antenna pattern for spaceborne microwave radiometer is proposed forth first time. As a result of simulation using this antenna pattern of sharing between spaceborne microwave radiometer and point to point fixed service stations. Lower sidelobe level leads to smaller interference and higher beam efficiency is design target of future spaceborne microwave radiometer in order to reduce bias error and interference.

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