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Spatial resolution enhancement of satellite-borne microwave radiometer using antenna pattern matching technique

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Abstract

Multi-frequency brightness temperatures measured by satellite-borne microwave radiometers including Advanced Microwave Scanning Radiometer-2 (AMSR2) represent responses from footprints with different sizes in frequencies. We ever developed and released the brightness temperature dataset (L1R product) corrected to identify the footprint sizes of different frequencies using the Backus-Gilbert (BG) method. Meanwhile, if we apply the BG method to synthesize a small antenna pattern using large antenna patterns, it is expected to enhance the spatial resolution of a satellite-borne microwave radiometer. This investigation is useful for the AMSR2 follow-on mission, too. We first defined a test case of antenna pattern synthesis for spatial resolution enhancement, and then investigated problems caused by applying the BG method on the test case.

1 Introduction

The Japan Aerospace Exploration Agency (JAXA) has operated the microwave radiometer, Advanced Microwave Scanning Radiometer-2 (AMSR2) on the GCOM-W (Global Change Observation Mission - Water) satellite since 2012. The AMSR2 observes multi-frequency microwave signals from C-band (6.925 GHz) to W-band (89 GHz) as a brightness temperature (T_B), but the footprint size of each frequency differs from one another. The higher frequency is, the smaller a footprint size becomes.

Therefore, we developed and released the brightness temperature dataset corrected to identify the footprint sizes of different frequencies [1]. In the L1R product, the most adequate weighting coefficients for small foorprints (i.e., antenna patterns) at a high frequency were first determined to replicate a large antenna pattern of a low frequency covered with them. The T_B values of the high frequency observed in the small antenna patterns were then synthesized (averaged) using the weighting coefficients. Thus, we could simulate the T_B of the high frequency observed in the large antenna pattern. This technique to fit small antenna patterns to a large one is known as the Backus-Gilbert (BG) method [2].

Meanwhile, JAXA is now investigating the AMSR2 follow-on mission, and the spatial resolution enhancement is one of the issues to be solved urgently in this mission. Indeed, the most definitive way to realize it is to expand the reflecting mirror size of a microwave radiometer, but there are still many technical challenges to rotate a large reflecting mirror to scan the Earth surface. Therefore, it deserves a consideration to realize spatial resolution enhancement by replicating a small antenna pattern from large antenna patterns using the BG method. In this paper, we present the details of problems caused by spatial resolution enhancement using the BG method.

2 Test case of resolution enhancement

The AMSR2 has two C-band channels (6.925 and 7.3 GHz), which is one of its major features. The nominal footprint size corresponding to -3 dB beam width is 35×62 (34×58) km at 6.925 (7.3) GHz in the direction of cross- and along-tracks. In the AMSR2 data, the original T_B image of these channels are most blurred.

According to our user survey, we have found that spatial resolution enhancement of C-band T_B values used to retrieve sea surface temperatures (SST) was most expected. Therefore, we defined a gaussian beam whose footprint size corresponding to -3 dB beam width is 32 km in diameter as a target antenna pattern. The area corresponding to -3 dB beam width of the target antenna pattern is equivalent to that of 10.65 GHz. In this paper, we defined as a test case of antenna pattern synthesis for spatial resolution enhancement.

Fig. 1 depicts synthesis of the target antenna pattern (F) using the antenna patterns of the 6.925-GHz vertical polarization (V) channel (Gs) at a swath center. The criteria of the antenna pattern synthesis are basically identical with those described in [1]. The center of F coincides with that of the antenna pattern of 10.65-GHz channel. The cutoff level of F and G was -30 dB (0.1%) of the maximum gain value.

In Figs. 1 (a) and (b), the thin-lined blue box represents the boundary of each Gs. The bold-lined green box in these figures represents the boundary of F. A representative G, F, the antenna pattern synthesized from Gs covering F ($\{G_i\}$) using weighting coefficients $\{a_i\}$ ($\sum a_i G_i$), and the discrep-

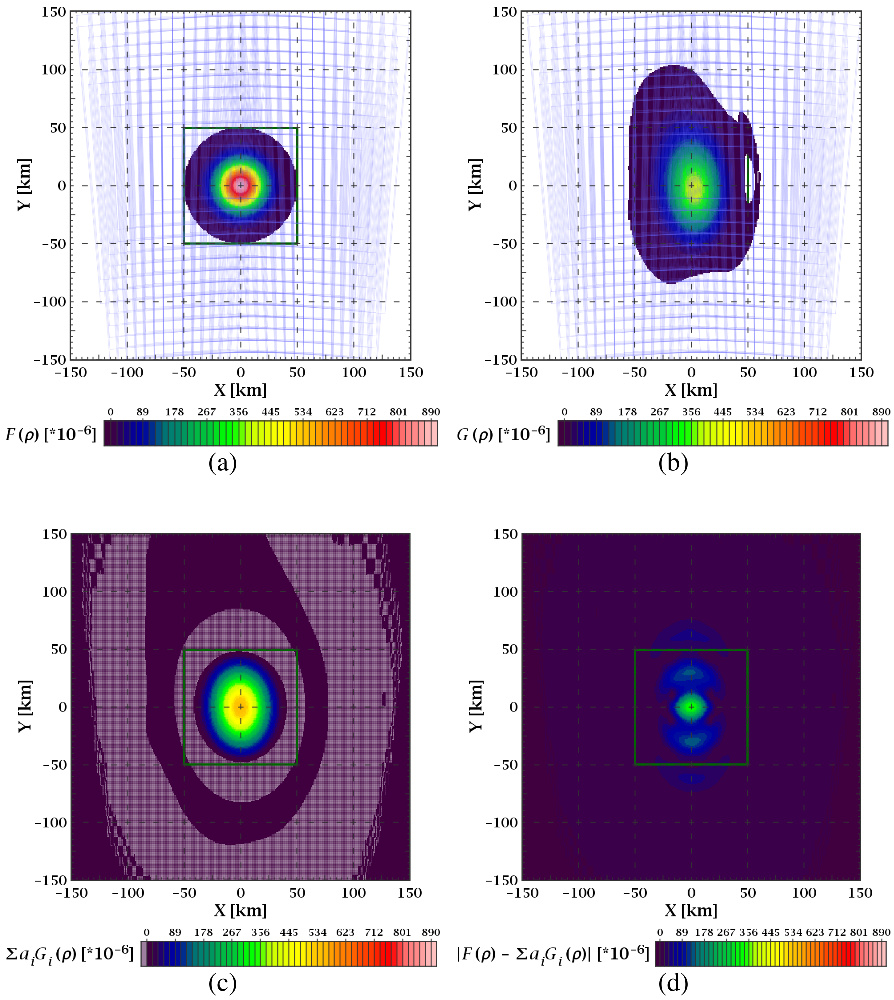

Figure 1: Synthesis of the target antenna pattern (F) using the antenna patterns of the 6.925-GHz V channel (Gs) at a swath center. The smoothing factor (κ) was 10^{-4}. 268 Gs were used to synthesize F. the Fit Error was 0.605, and particularly the Fit Error outside F was 0.21. (a) F. (b) G. (c) $\sum a_i G_i$. (d) $|F - \sum a_i G_i|$.

ancy between $\sum a_i G_i$ and F ($|F - \sum a_i G_i|$) are colored using the same legend. The volume of $|F - \sum a_i G_i|$ is the Fit Error, which indicates the quality of antenna pattern synthesis. In this antenna pattern synthesis, the Fit Error was 0.605. In particular, Fig. 1 (c) indicates $\sum a_i G_i$ had sensitivities outside F, and the Fit Error outside F was 0.21. When we synthesized a large antenna pattern using small antenna patterns for the L1R product, the Fit Errors were always less than 0.4, and they appeared inside F. Therefore, it was a major feature seen in the Fit Error from large Gs to small F.

3 Problems

We then obtained T_B map synthesized using weighting coefficients calculated in Section 2. We call this weighting coefficient set as the RE0 filter (RE: resolution enhancement) in this paper. Fig. 2 depicts distributions of T_B at 6.925-GHz V channel ($T_{B6.925\mathrm{V}}$) before and after applying the RE0 filter. $T_{B6.925\mathrm{V}}$ values before applying the RE0 filter are original values measured by AMSR2.

As indicated by arrows in Fig. 2 (b), we noticed two problems for the RE0 filter:

1. emphasis of stripes along scan lines
2. microwave signals exuding from a land along coastlines

As for the problem (1), we can see stripes slightly even in Fig. 2 (a) before applying the RE0 filter. These stripes must have been caused by a gain fluctuation of the receiver included in $T_{B6.925\mathrm{V}}$. The amplitudes of these stripes were almost within a noise equivalent differential temperature (NEΔT, ± 0.34 K for $T_{B6.925\mathrm{V}}$). The stripes seen in Fig. 2 (a) were emphasized by the RE0 filter. This problem was caused by the hardware limitation of the AMSR2, but we have to solve it to realize practical spatial resolution enhancement.

The problem (2) was caused by the sensitivities of the synthesized antenna pattern ($\sum a_i G_i$) outside the target antenna pattern (F). It is more important to reduce the sensitivities of $\sum a_i G_i$ outside F than to reduce those of $\sum a_i G_i$ inside F.

References

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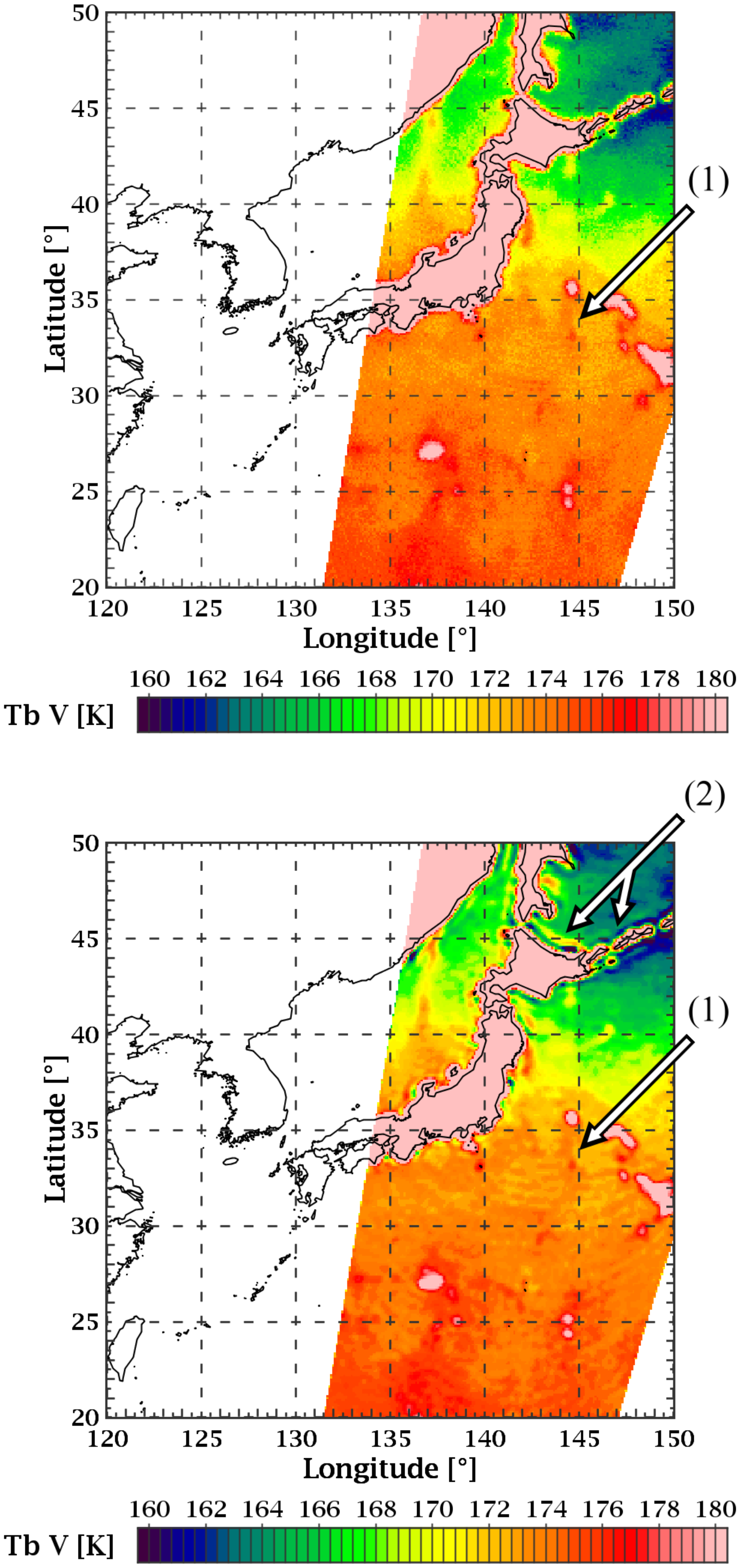

(b)

Figure 2: $T_{B6.925\mathrm{V}}$ distributions. (a) before applying the RE0 filter (L1B). (b) after applying the RE0 filter calculated in Section 2. As indicated by arrows, we could see two problems: (1) emphasis of stripes along scan lines and (2) microwave signals exuding from a land along coastlines.