PROCEEDINGS OF ISAP '92, SAPPORO, JAPAN

Attenuation and Backscatter Properties of Bright-Band Computed at 13.8 GHz

Jun Awaka
Hokkaido Tokai University
Minami-ku, Minami-sawa 5-1-1-1, Sapporo 005, Japan

1. INTRODUCTION

For a successful observation of rain by air-borne or space-borne radars, detailed study of the propagation characteristics of radio waves through bright-band, i.e. melting layer, is important because the radar signal passes through the bright-band twice: first on its way to the rain region, and second on its return way from the rain region.

This paper studies the attenuation and backscatter properties of bright-band by two models[(1)-(3)] at a frequency of 13.8 GHz, which frequency is to be used by the TRMM (Tropical Rainfall Measuring Mission) space-borne rain radar[(4)].

2. OUTLINE OF MODELS

Figure 1 illustrates the assumed shape of bright-band particles. The first bright-band model (Model A) assumes spherical bright-band particles[(1)-(2)]. The composition of each particle is assumed to be a uniform mixture of water, ice, and air. The volume content of water in a snow particle increases with the progress of melting process.

The second bright-band model (Model B) assumes concentric spherical particles. Each particle has a spherical snow core which is covered with water[(3)]. The composition of snow core is assumed to be a uniform mixture of ice and air. The melting ratio, which is defined as the ratio of mass of liquid water to total mass of a particle, increases with the progress of melting process.

Figure 2 outlines the computation procedure for Model A and that for Model B. For simplicity, this paper assumes that there is not any coalescence and/or breakup of particles in both rain and bright-band regions. In this case, the drop-size distribution of bright-band particles can be derived from the drop-size distribution of raindrops.

Three negative exponential type drop-size distributions of raindrops, that is Marshall and Palmer (MP) distribution[(5)], Joss thunderstorm (J-T) distribution, and Joss drizzle (J-D) distribution[(6)], are used for the computation of Z-factor and attenuation coefficient of bright-band by Mie's theory.

In the radar observation from space, the following quantity, Z_{obs} is observed by a radar which has an infinitestimally small range resolution (in the actual situation, however, averaged value of the following quantity within the range resolution is observed).

$$Z_{obs}(h) = Z(h)10^{-0.2\int_0^{h_0-h}\alpha(x)dx} \quad (\text{for } h_o \geq h) \tag{1}$$

where Z is the Z-factor [mm^6/m^3], α is the attenuation coefficient [dB/km], h is the height [km], and h_0 is the origin of the height [km] which is taken at the top of the 0°C isothermal layer. This paper assumes that the attenuation term can be ignored when $h > h_o$, which means that the attenuation in the dry snow region above the bright-band is zero.

3. RESULT OF COMPUTATIONS

Figures 3(a), (b), and (c) show height profiles of Z_{obs} computed by Model A, Model B with the density of snow core, ρ_s, being 0.05 g/cm^3, and Model B with different ρ_s (ρ_s=0.2 g/cm^3), respectively. The Marshall-and-Palmer drop-size distribution is assumed in the computation. Very large attenuation in Model B at higher rainfall rate makes Z_{obs} very small at lower height. A similar effect also appears in the case of Model A, but with lesser extent.

It is empirically known that the bright-band usually appears above the rain region with weak or moderate rainfall rates in the case of stratiform type rain. Therefore the attention should be paid to the case of weak and moderate rainfall rates region in these figures, where the effect of attenuation is rather small.

It is important to study whether the attenuation effect of bright-band can be ignored or not for the radar observation of rain from space. Figures 4(a) and (b) show the two-way attenuation through bright-band, which is defined as follows:

$$ATT = 2\int_0^{h_0-h} \alpha(x)dx \quad \text{[dB]} \tag{2}$$

Figures 4(a) and (b) show the case where $h_0 - h$ = 0.7 km and 1.0 km, respectively. The figures clearly show that the attenuation effect of bright-band strongly depends on models. The attenuation also depends on drop-size distributions.

Table 1 summarizes the maximum rainfall rate below which the bright-band attenuation is less than 0.5 dB.

4. CONCLUSION

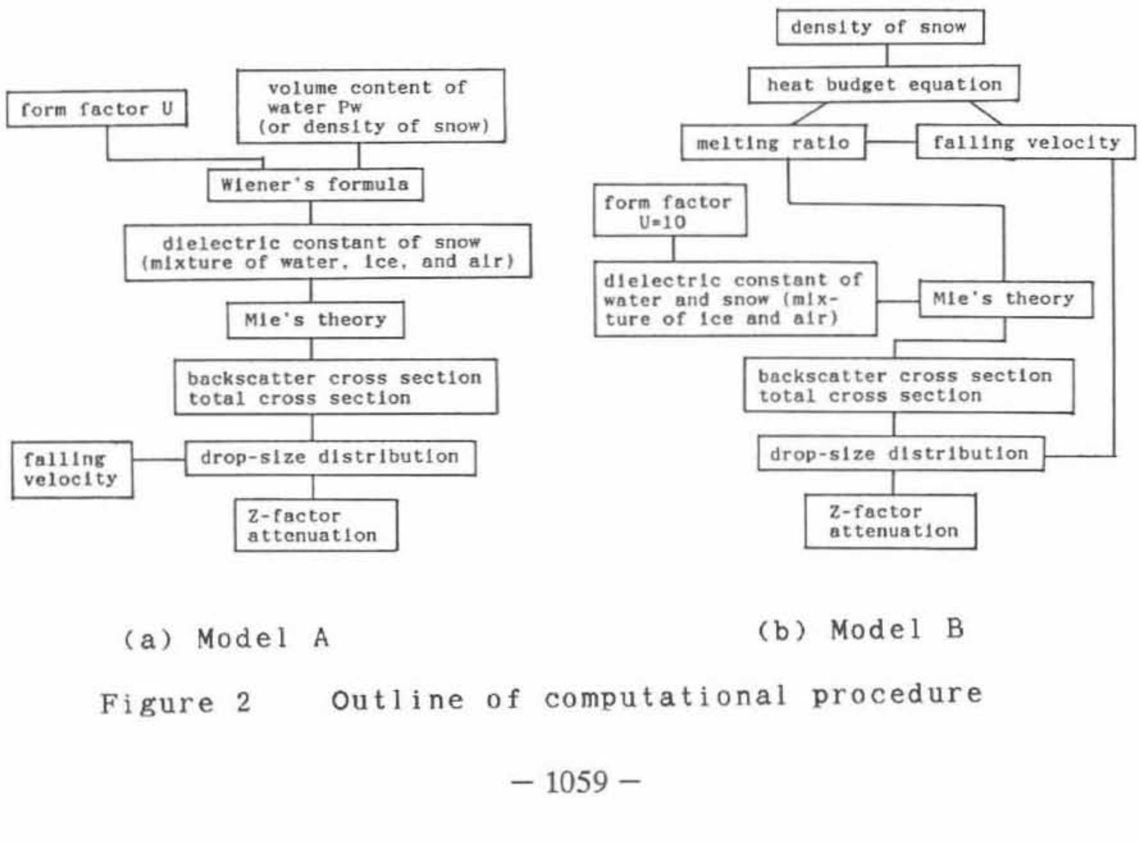
Attenuation and backscatter properties of bright-band are examined by a spherical composite dielectric model (Model A) and by a concentric spherical model (Model B). It is found that these scattering properties of bright-band strongly depend on models. They also depend on drop-size distributions. At a rainfall rate being less than a few mm/h, the two-way attenuation of bright-band is less than 0.5 dB and the effect of bright-band attenuation may be safely neglected in the rain observation from space. When the rainfall rate increases, however, the effect of bright-band attenuation becomes larger and it has to be incorporated into a rainfall-rate retrieval algorithm, which requires further theoretical and experimental studies on bright-band.

REFERNCES

[1] Nishitsuji, A. et al.; "An analysis of propagation character at 34.5 and 11.5 GHz between ETS-II satellite and Kashima station", Trans. IECE Japan, J66-B, pp.1163-1170, 1983 (in Japanese).
[2] Awaka, J. et al.; "Model calculations of scattering properties of spherical bright-band particles made of composite dielectrics", J. Radio Res. Lab., vol.32, No.136, pp.73-87, 1985.
[3] Yokoyama, T. and H. Tanaka; "Microphysical process of melting snowflakes detected by two-wavelength radar: Part I", J. Meteor. Soc. Japan, vol.62, No.4, pp.650-666, 1984.
[4] Nakamura, K. et al.; "Conceptual design of rain radar for the Tropical Rainfall Measuring Mission", Int. J. Sat. Commun., vol.8, pp.257-268, 1990.
[5] Marshall, J.S. and W.M. Palmer; "The distribution of raindrops with size", J. Meteorol., vol.5, pp.165-166, 1948.
[6] Joss, J. and A. Waldvogel; "Raindrop size distribution and sampling size errors", J. Atmos. Sci., vol.26, pp.566-569, 1969.

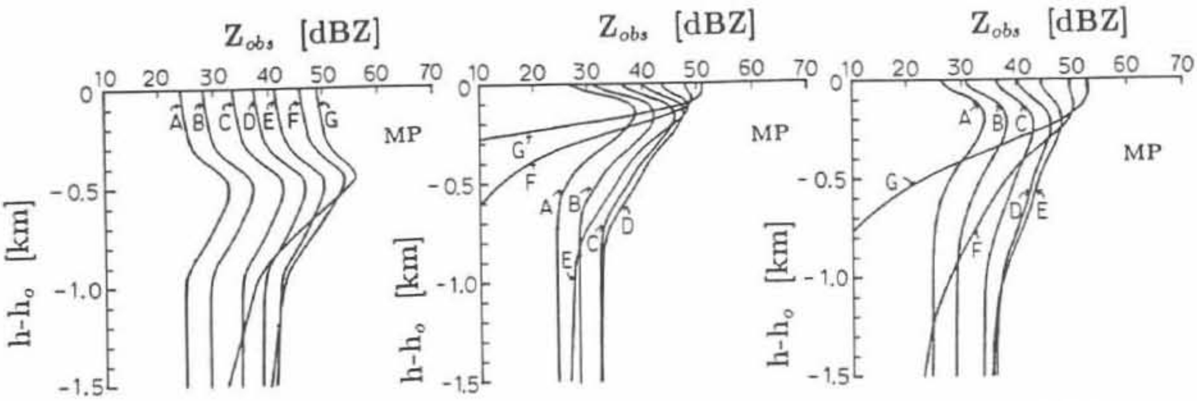
(a) Model A　　(b) Model B

Figure 1　Shape of bright-band particle



(a) Model A　　(b) Model B

Figure 2　Outline of computational procedure



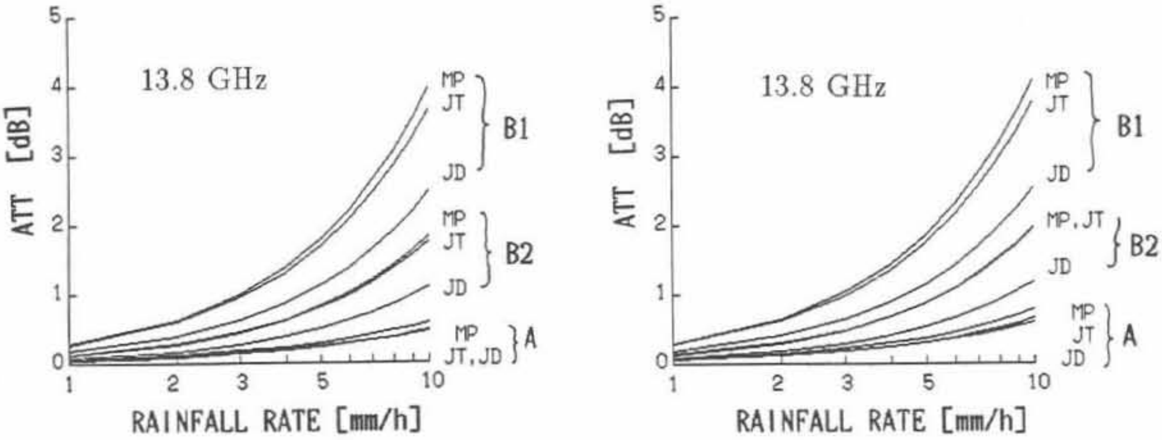
(a) Model A

(b) Model B (ρ_s=0.05 g/cm^3)

(c) Model B (ρ_s=0.2 g/cm^3)

Figure 3 **Height profile of Z_{obs}**

A: 1 mm/h, B: 2 mm/h, C: 5mm/h, D: 10 mm/h,
E: 20 mm/h, F: 50 mm/h, G: 100 mm/h



(a) path length = 0.7 km

(b) path length = 1.0 km

Figure 4 **Two-way bright-band attenuation, *ATT*, vs. rainfall rate**

A: Model A, B1: Model B (ρ_s=0.05 g/cm^3), B2: Model B (ρ_s=0.2 g/cm^3)

Table 1 **Rainfall rate below which the two-way bright-band attenuation is less than 0.5 dB**

$h_0 - h$	Model A			Model B ρ_s=0.05 g/cm^3			Model B ρ_s=0.2 g/cm^3		
	MP	J-T	J-D	MP	J-T	J-D	MP	J-T	J-D
0.7 km	8.5	10	11	1.6	1.7	2.5	3.3	3.3	5.0
1.0 km	5.4	7.8	8.3	1.6	1.6	2.4	3.1	3.1	4.8

The number without unit indicates the rainfall rate in [mm/h]
MP: Marshall & Palmer, J-T: Joss thunderstorm, J-D: Joss drizzle