THE NIED DUAL-FREQUENCY CLOUD RADAR SYSTEM UNDER DEVELOPMENT

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1. INTRODUCTION

National Research Institute for Earth Science and Disaster Prevention (NIED) has investigated rainfall and snowfall clouds, especially that caused disasters, using X-band Doppler and polarimetric radars. But we could not observe all stages through a life cycle of cloud and precipitation system because non-precipitating clouds cannot be observed with X-band radars. So we are developing a dual-frequency cloud radar system under contract with Mitsubishi Electric Corporation, and it will be completed at the end of March 2000. It will be useful for observation researches of not only cloud's affection to the redistribution of energy and water in the climate system bur also cloud and precipitation systems.

We will introduce outlines of our developing cloud radar system in this paper.

2. OUTLINES OF THE SYSTEM

Figure 1 shows the outside appearance of our developing cloud radar system. The radar system is mounted on a truck of 4-tons for field experiments. This truck can be driven with normal auto-driving license in Japan. The system uses a single two-meter diameter Cassegrain antenna to make collocated measurements at both Ka- and W-bands, and it is mounted at the rear. W-band transmitter and receivers are mounted behind the antenna mirror and a part of receiver for Ka-band near the antenna pedestal. The other devices are installed in the shelter.

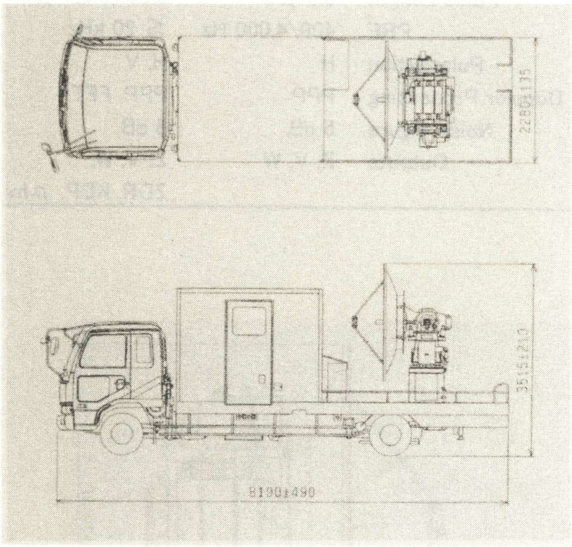

Fig. 1: Outside appearance of developing cloud radar system. Unit is mm.

Main specifications of developing dual-frequency cloud radar system are listed in Table 1. The transmitting frequencies are 35 GHz (Ka-band) and 95 GHz (W-band). The first remarkable character of this cloud radar system is the adoption of a single two-meter diameter Cassegrain antenna to make collocated measurements at both Ka- and W-band. The antenna can scan full circle in

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Table 1: Specifications of developing cloud radar system

	Ka-band	W-band
Frequency	35 GHz	95 GHz
Antenna Type	Cassegrain, 2 mϕ	
Scan Range	AZ: Full circle ($\leqq$ 24 deg/s)	
(Scan Rate)	EL: -2 to +182 deg ($\leqq$ 12 deg/s)	
Antenna Gain	52 dB	58 dB
Beam Width	0.4 deg	0.2 deg
Transmitter Tube	Magnetron	Klystron (EIA)
Peak Power	100 kW	1.5 kW
Pulse Length	0.5 μs	0.25 to 2.0 μs
PRF	400/4,000 Hz	$\leqq$ 20 kHz
Polarization	H	H, V
Doppler Processing	PPP	PPP, FFT
Noise Figure	5 dB	8 dB
Outputs	Z, V, W	Z, V, W, ZDR, KDP, ρhv

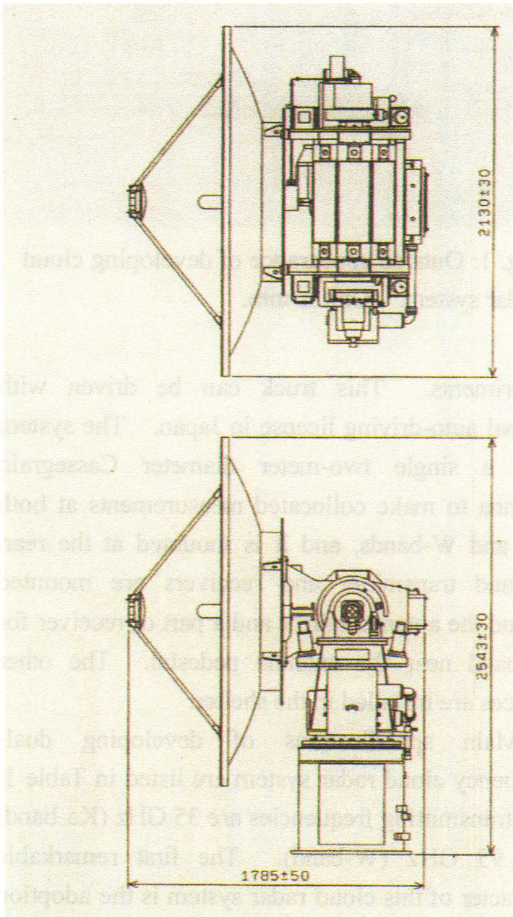

Fig. 2: Appearance of the antenna for common use by Ka- and W-band. Unit is mm.

Fig. 3: Photograph of the antenna in the factory.

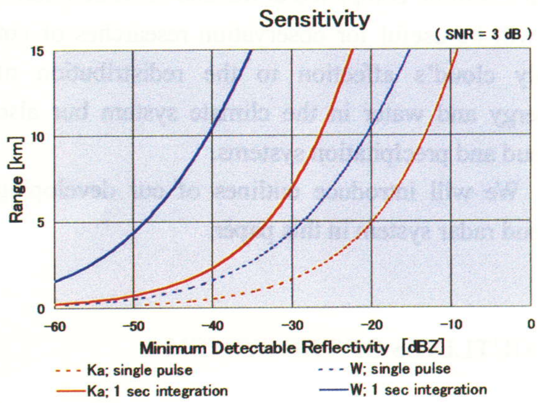

Fig. 5: Sensitivity of the developing radar system for 3 dB signal-to-noise ratio, given a 0.5 and 1.0 μs transmit pulse for Ka- and W-band. Red and blue dashed lines show sensitivities at Ka- and W-band with single pulse. Red and blue solid curves show sensitivities at Ka- and W-band with one-second integration, respectively.

azimuth and –2 to +182 degree in elevation at the maximum speed of 24 deg/s in azimuth and 12 deg/s in elevation. Antenna gains are 52 and 58 dB, and beam-widths are 0.4 and 0.2 degree at Ka- and W-band, respectively.

The appearance of the antenna is shown in Fig. 2. W-band transmitter and receivers are mounted behind the main mirror. Figure 3 is the photograph of the antenna in the factory. There are horn antennas at the center of main mirror and W-band circular horn is put between Ka-band horn array from the top and bottom.

The transmitter tubes are a magnetron at Ka-band and an EIA (Extended Interaction Klystron Amplifier) at W-band. The peak powers are 100 kW and 1.5 kW, pulse lengths are 0.5 μs and 0.25 to 2.0 μs, PRFs are 4,000/400 Hz (double pulse) and 20 kHz maximum, and noise figures are 5 and 8 dB at Ka- and W-band, respectively.

Doppler measurements are available at both frequencies. Ka-band subsystem realizes Doppler velocity range of about ±8.5 m/s within the limitation of duty cycle of 0.05 % by the adoption of the double pulse operation.

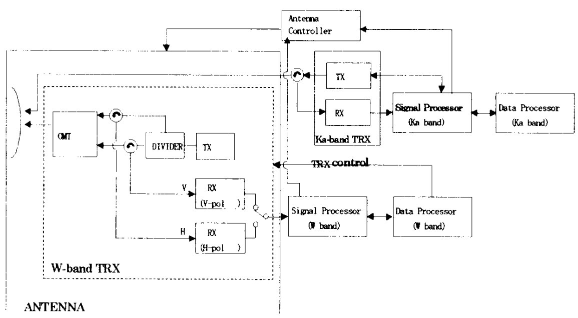

Fig. 4: Block diagram of the developing system.

Polarimetric measurement is available at W-band and we can derive parameters ZDR, ρhv and KDP. Unfortunately we cannot measure LDR because the antenna has complex structure and the isolation between both polarizations is not enough to measure cross-polarization signals. Figure 4 shows the block diagram of the system. The left-hand side shows single antenna for common use, and right-hand side upper part shows the Ka-band subsystem, and lower part shows W-band subsystem. W-band transmitter and receivers are mounted behind the antenna mirror and there are two receivers for vertical polarization signal and horizontal polarization. W-band subsystem can measure polarimetric parameters, ZDR, ρhv and KDP. The RVP7 by SIGMET is adopted as the radar signal processor of each subsystem. Data are recorded on DAT (DDS3).

Sensitivity can be improved by $N^{1/2}$ if N pulses with uncorrelated noise are averaged. Figure 5 shows the relationships between minimum detectable reflectivity dBZ and range km for 3 dB signal-to-noise ratio, given a 0.5 and 1.0 μs transmit pulse for Ka- and W-band. Red and blue dashed lines show sensitivities at Ka- and W-band with single pulse. Red and blue solid curves show sensitivities at Ka- and W-band with one-second integration. With one-second integration, Ka-band minimum reflectivity is less than –26 dBZ at the range of 10 km, and less than –48 dBZ at 5 km as to W-band. The numbers of pulse integration are 450 for Ka-band and 10-thousand for W-band.

3. RESEARCH THEME AND OBSERVATION PLAN

3.1 *Research Theme*

We will study two research themes using the cloud radar system at first. First theme is on the methodology, we will study on the estimation methods of cloud parameters such as liquid/ice water content, drop size distribution, terminal velocity and classification of cloud drops using Doppler, polarimetric and dual-frequency techniques. In this field, several groups have published excellent results (e.g., Babb, *et al.*, 1999; Pazmany, *et al.*, 1994; Matrosov, 1992; Sekelsky and McIntosh, 1996). The results of this study will become the basis of all the other researches.

The second theme is the study of cloud formation and precipitation processes. We expect to observe a series of processes schematically shown in Fig. 6 from the stage of water vapor

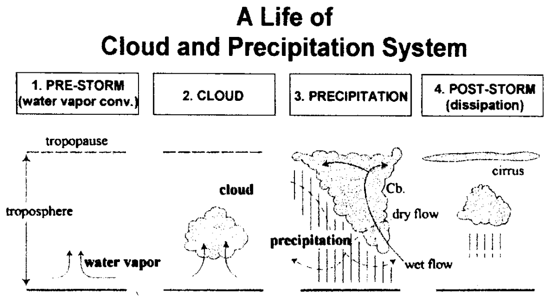

Fig. 6: Schematic picture of a life of cloud and precipitation system.

convergence, cloud formation, precipitation to their dissipation using the cloud radar in combination with the other observation facilities.

In addition, observation results should be compared with the results of numerical simulations by our developing cloud model. Cloud particles and hydrometeors with their diameters from 5 μ m to 8 mm are classified into 4 types and 34 size-bins of each type in the non-hydrostatic and anelastic model, and it includes microphysical processes in detail. We hope to deeply understand cloud and precipitation systems by this study.

We think the theme on the radiative properties of clouds is so important, because the role of clouds in the global climate system has not yet resolved. But we will use our developing cloud radar to study these two themes at the first.

3.2 *Observation Plan*

We are planning the following observations to study the themes described previous subsection. They include several cooperative observations with the other organizations.

From April 2000, we will start the test observation to check the system performance, then observation of various types of clouds and precipitation around Tsukuba. We can use simultaneously our X-band polarimetric/Doppler radar and microwave radiometer, and in-situ observation by video sondes will be carried out at the time of cirrus cloud observation.

May be autumn in 2000 and 2001, around Tsukuba, we will make cloud radar observation in the same period with water vapor tomography observation using fine GPS-network by GPS-meteorology group. We also try to make dual Doppler observation with Ka-band Doppler radar of Mitsubishi Electric Corporation in 2001.

In February, 2001 and 2002, we will carry out cloud radar observation of snow clouds in combination with in-situ observation by an instrumented aircraft and video sondes by the Ministry of Construction and Meteorological Research Institute in Niigata Prefecture, Japan.

We will transport our cloud radar to the Palau Islands, for the observation of clouds in the tropics in 2003.

4. CONCLUSIONS

A dual-frequency, polarimetric/Doppler cloud radar system is developing by National Research Institute for Earth Science and Disaster Prevention. Several cooperative observations are planned to retrieve cloud parameters and understand cloud and precipitation systems.

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