Onboard Calibration of the Dual-frequency Precipitation Radar (DPR) installed on the Global Precipitation Measurement (GPM) core observatory

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Abstract

Onboard calibration method of the Dual-frequency Precipitation Radar (DPR) installed on the Global Precipitation Measurement (GPM) core observatory, launched in February 2014, is described. The orbital check out status of DPR will be reported.

1. Introduction

The Global Precipitation Measurement (GPM) mission is a comprehensive program to measure precipitation from space, similar to but much expanded beyond the Tropical Rainfall Measuring Mission (TRMM)[1]. Its scope is not limited to scientific research, but includes practical and operational applications such as weather forecasting and water resource management. To meet the requirements of operational use, the GPM uses multiple low-orbiting satellites to increase the sampling frequency and to create three-hourly global rain maps that will be delivered to the world in quasi-real time. The GPM core observatory is equipped with a dual-wavelength radar (DPR) and a microwave radiometer, and works as a reference standard for the GPM constellation radiometers. The DPR, developed by Japan Aerospace Exploration Agency (JAXA) and National Institute of Information and Communications Technology (NICT), consists of Ku-band (13.6 GHz) radar suitable for heavy rainfall in the tropical region, and Ka-band (35.55 GHz) radar suitable for light rainfall in higher latitude region[2]. Rain echoes measured with the DPR provides us with some drop size information of precipitation that will help improve the rain rate estimation in comparison with the single-frequency algorithm used for the TRMM Precipitation Radar. The major uncertainties in the possible DPR rain retrieval algorithm consist of two kinds of errors, i.e., errors related to hardware and inherent fluctuation of signals and errors related to storm and surface models. The former includes radar calibration errors, data fluctuation due to fading, data quantization error, and beam mismatching, and the latter includes biases caused by misidentification of the phase state of hydrometeors and by non-uniform distribution of precipitation within a field of view[3]. To minimize both radar calibration errors and beam mismatching, onboard calibration of the DPR is performed with radar calibrators.

2. Dual-frequency Precipitation Radar (DPR)

Figure 1 shows the concept of precipitation measurement by the GPM core observatory. The configuration of precipitation measurement using an active radar and a passive microwave radiometer (MWR) is similar to TRMM. The major difference is that DPR consists of two radars, Ku-band (13.6 GHz) radar (KuPR) and Ka-band (35.55 GHz) radar (KaPR). The inclination of the core observatory is 65 degrees, and the flight altitude is about 407 km. The non-sun-synchronous circular orbit is necessary for measuring the diurnal change of rainfall. Figure 2 and 3 shows the concept of dual-frequency measurement of precipitation. According to the different detectable dynamic ranges, the KaPR will detect snow and light rain, and the KuPR will detect heavy rain. Using two wavelength data, two parameter raindrop size distribution could be retrieved, which would result in precise rain retrieval.

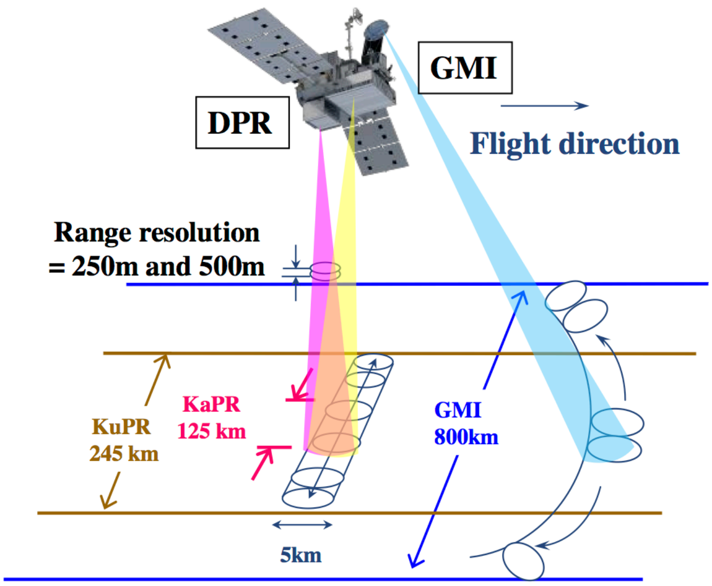

Fig. 1 Concept of precipitation measurement with GPM core observatory

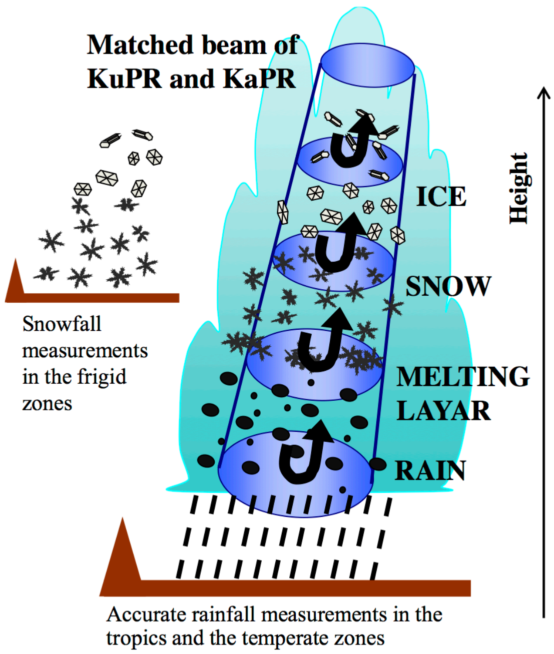

Fig. 2 Vertical precipitation structure

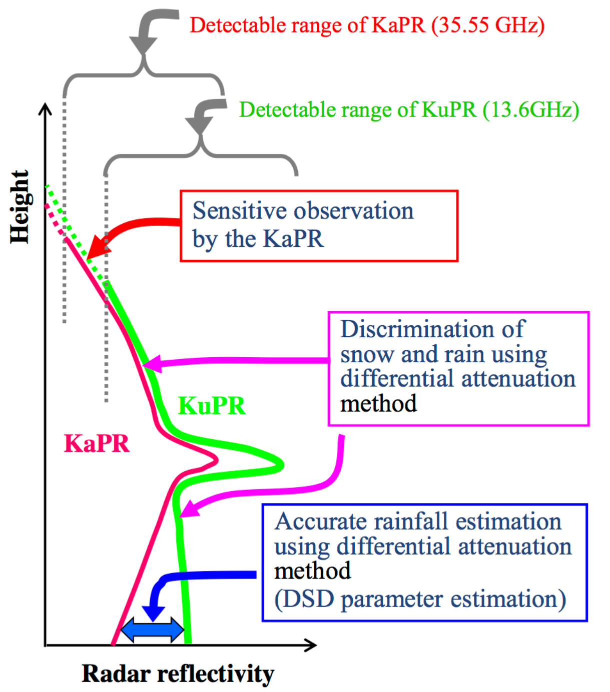

Fig. 3 Concept of rain profiling algorithm for DPR

Specification of DPR (KuPR + KaPR) is shown in Table 1. KuPR is similar to TRMM/PR in frequency, but the KuPR sensitivity is almost two times better than that of TRMM/PR since the transmit power of KuPR is twice of TRMM/PR. KaPR has two observation mode, "High Sensitivity Mode" and "Dual-frequency Mode". The former is the most sensitive because of longer transmit pulse. The latter is used for the matched beam observation with KuPR.

Table 1 Specification of DPR (KuPR + KaPR)

	KaPR		KuPR	TRMM PR
Radar Type	Active Phased Array (128 elements)			
Antenna Type	Slotted Waveguide Antenna			
Frequency	35.547 & 35.553 GHz		13.597 & 13.603 GHz	13.796 & 13.802 GHz
Peak Power	> 140 W		> 1000 W	> 500 W
PRF	Variable PRF (VPRF) 4000 – 4500 Hz			Fixed 2776 Hz
Beam Width	0.71 degrees			
Scanning	Cross-Track ±8.5 degrees from nadir		Cross-Track ±17 degrees from nadir	
Altitude	407 km			350 km
Swath	125 km		245 km	215 km
Horizontal Resolution	5 km			4.3 km
Observation Mode	High Sensitivity	Dual-Frequency	—	—
Transmit Pulse Width	3.2 μs (x2)	1.6 μs (x2)	1.6 μs (x2)	
Range Resolution	500 m	250 m	250 m	
Observation Altitude	Upto 19 km from ground (mirror image around nadir)			15km to -5km (mirror image at nadir)
Sensitivity	12 dBZ 0.2 mm/hr	18 dBZ 0.5 mm/hr		23 dBZ 0.7 mm/hr
Accuracy	< ±1 dB			

3. Calibration of the DPR

Calibration of the DPR consists of two types, external and internal calibration shown in Figure 4. The former is absolute calibration of all radar parameters with some radar calibrators deployed on the ground, but the occasion is rare. The latter is limited calibration on FCIF, which generates transmit signal and down-converts received signal, and SCDP, which ditizes and records down-converted received signal, but more frequent.

Figure 5 describes external calibration with RxRC (=Receiving Radar Calibrator). Transmit signal of DPR is short pulse wave series, and RxRC records the power, pulse width, and pulse interval of these signals.

Figure 6 describes external calibration with TxRC (=Transmit Radar Calibrator). In case of simple TxRC, a certain level of CW (Continuous Wave) is transmitted, and received power at DPR is recorded.

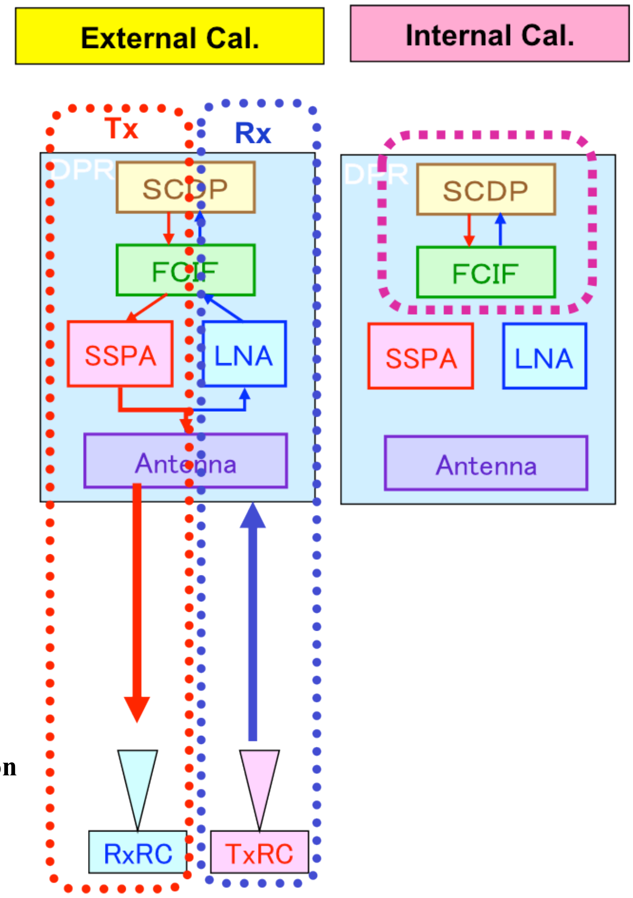

Fig. 4 Two types of calibration (External and Internal)

4. References

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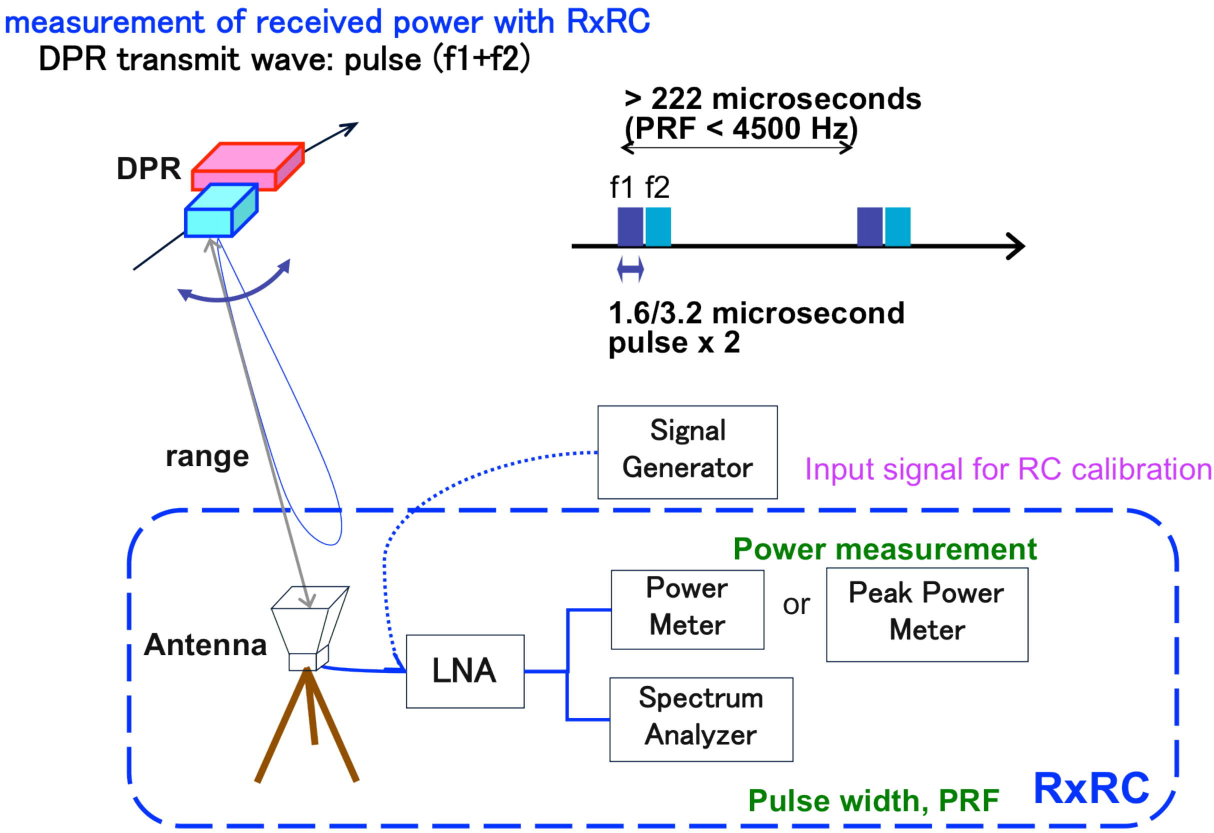

Fig. 5 External calibraton: RxRC (Receiving Radar Calibrator)

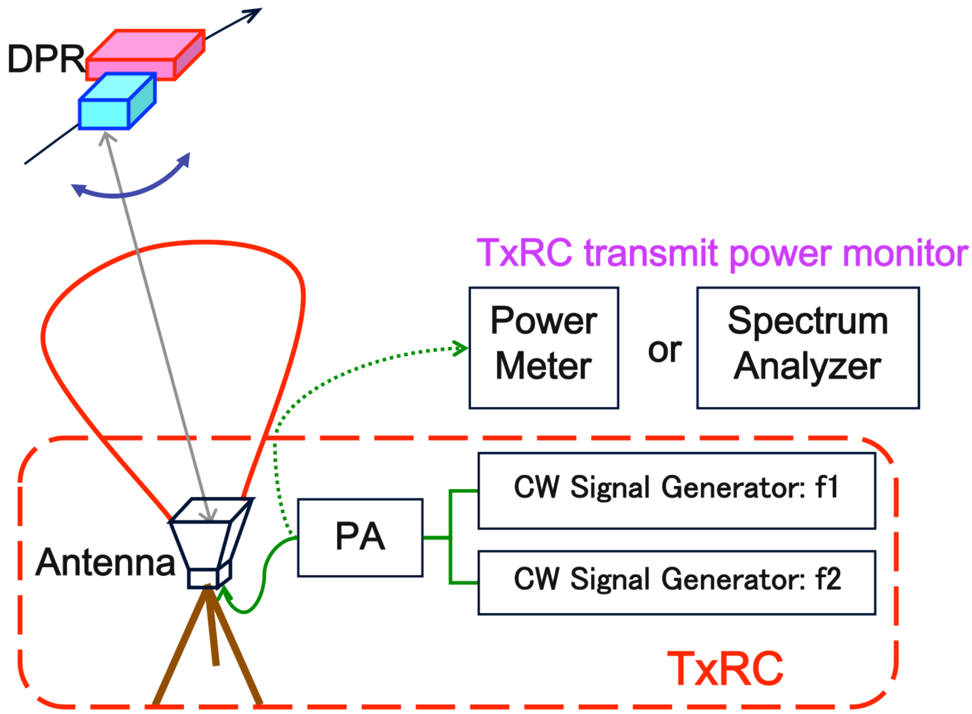

Fig. 6 External calibration: TxRC (Transmit Radar Calibrator)