Space Based Precipitation Measurement with a CubeSAT

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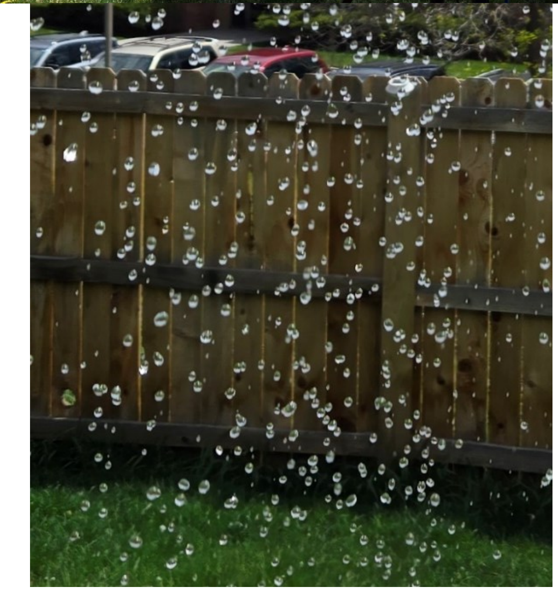
Precipitation Measurement Satellite

- The Cloud Profiling Radar on satellite is developed under cooperation of National Institute of Information and Communications Technology (NICT) and Japanese Aerospace Exploration Agency (JAXA) in Japan
- First spaceborne Doppler radar for cloud and precipitation

Precipiation Measurement Satellite

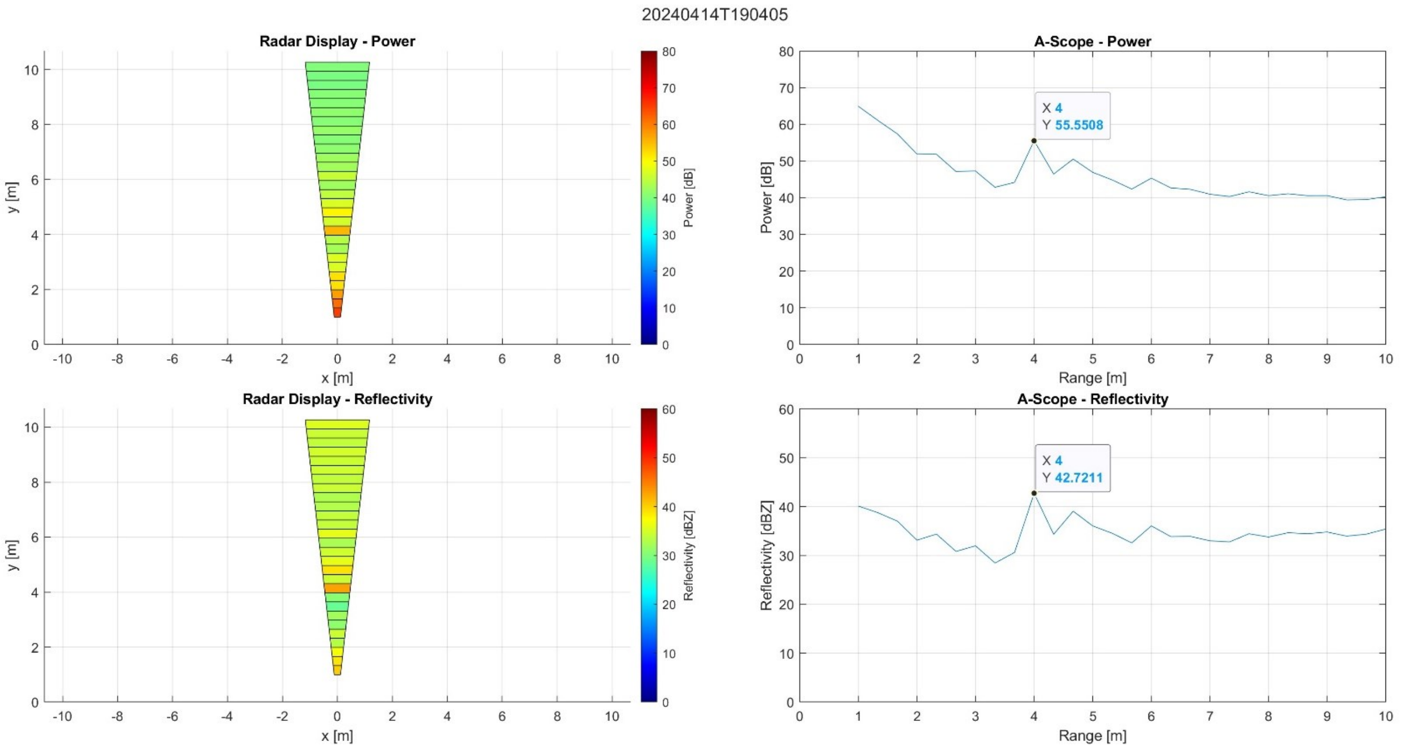
- CPR has two objectives, which are to measure profile of clouds reflectivity and to measure up/down velocity of clouds
- Then the requirement of sensitivity is -35dBZ after 20km integration and the requirement of Doppler velocity measurement accuracy is less than 1 m/s after 10km integration for more than -22 dBZ of clouds
- The large antenna has large footprint and uses phased arrays

Calibration Mechanism of Payload



Calibration Mechanism

- 12-inch diameter sphere located 4 m from the radar
- Radar Cross Section: $\sigma = \pi r^2 = 0.073\ m^2$
- Received Power (at antenna): $P_r = \frac{P_t G^2 \lambda^2}{(4\pi)^3 r^4} \sigma$
- Receiver Power: $P_o = G_{rx} P_r$
- Radar Constant: $C = \frac{G_{rx} P_t G^2 \pi^3 |k_w|^2 \Delta r \sin\frac{\theta}{2} \sin\frac{\varphi}{2}}{128 \times 10^{18} \lambda^2 \ln 2}$
- Equivalent Reflectivity: $Z_e = \frac{P_o r^2}{C}$
- $dBZ = 10 \log_{10} Z_e$ = 41.6 dBZ
- Measured Reflectivity: 42.7 dBZ



Precipitation Radar Equation

Radar Equation

$$P_r = \frac{P_t G^2 \lambda^2 \theta^2 c\tau}{2^{10}\pi^2 (\ln 2) R^2} \frac{1}{L} \frac{\pi^5 |K|^2}{\lambda^4} 10^{-18} \cdot Z \cdot 10^{-0.2\int_0^r k dr}$$

Radar Equation
Pt: Transmitting Power at Antenna Feed [mW]
Pr: Received Power at Antenna Feed [mW]
λ: Wave Length [m]
G: Antenna Gain [dBi]
θ: Half Power Antenna Beam Width [(radian)]
c: Velocity of Light [m/s]
τ: Pulse Width [s]
R: Range form CPR to surface [m]
K: Dielectric Constant = (m2-1)/(m2+1) [unit]
m: diffractive index of target
k: Attenuation Coefficient (cloud and atmosphere) [dB/km]
Z: Radar Reflectivity Factor [mm6/m3]
L: Calibration Factor or System Loss [unit]

OBJECTIVES of external calibration

- ✓ Define calibration factor of radar in Radar Equation
- ✓ Define transmitting power
- ✓ Define receiving power
- ✓ Define antenna pattern (Beam Pointing)

PROBLEM

Too narrow foot print

Possible External Calibration Methods

- ➢ using ARC (Active Radar Calibrator) - (need feasibility study)
- ➢ using natural distributed target (sea surface, etc)

Active Radar Calibrator

- Key issues for external calibration using ARC

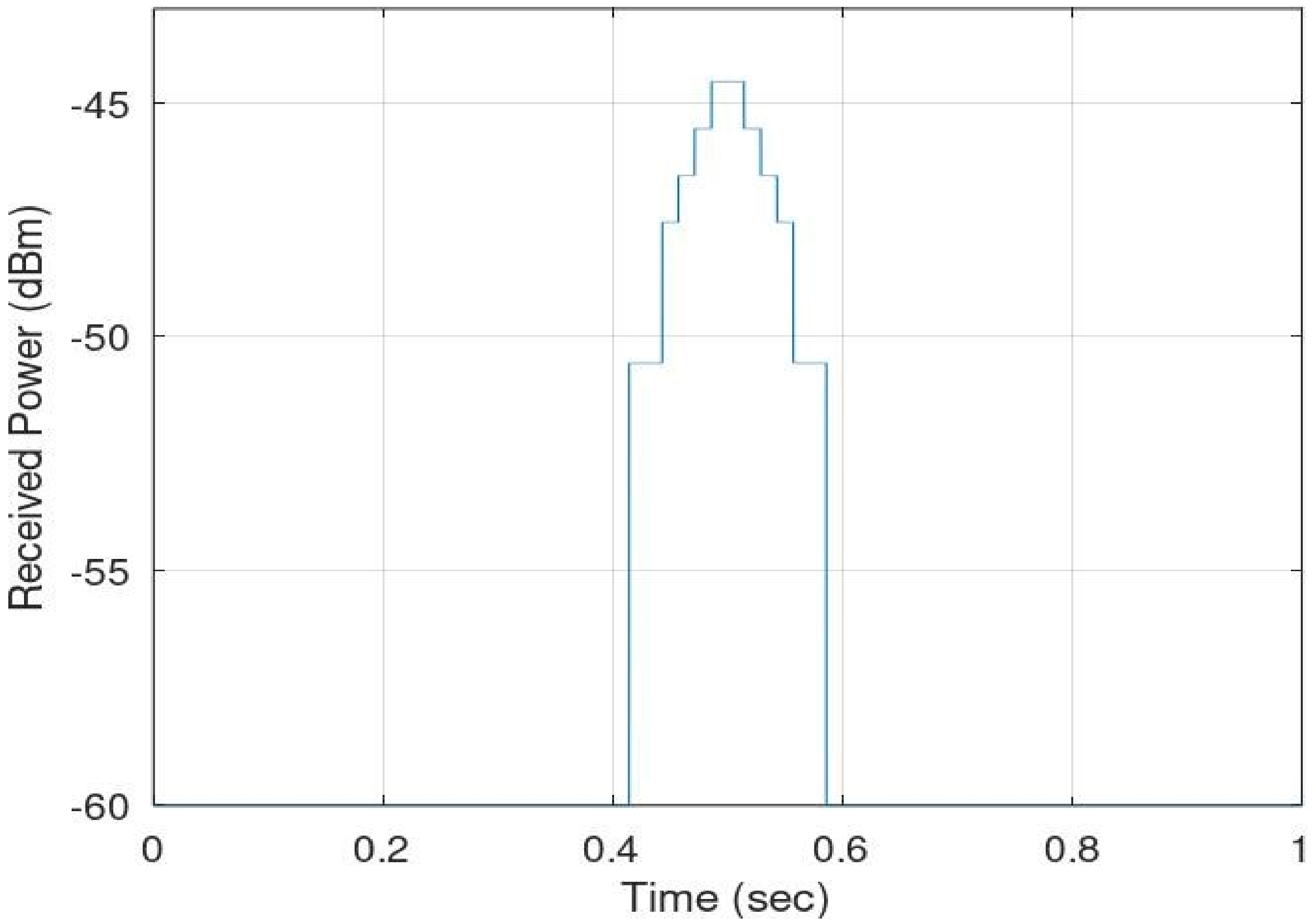
(1) Prediction of Satellite Track and Overpass Time

(2) Place ARC to exact location predicted

(3) Reconstruction of Transmitting Pulse Shape

(4) Reconstruction Antenna Pattern

Calibration Error



Conclusion

- The performance of external calibration using ARC is shown by the feasibility experiment.
- The amplitude measurement results including the reception of cross-polarized signal by accident are agreed within sufficient error.
- From the phase measurement result, the antenna pointing is estimated not within the range of error.
- Known key issues of external calibration for CPR are followings;
    (1) Prediction of Satellite Track and Overpass Time
    (2) Place ARC to predicted position
    (3) Examination at exact timing
    (4) Reconstruction Antenna Pattern
    (5) Reconstruction of Transmitting Pulse Shape

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Thank You