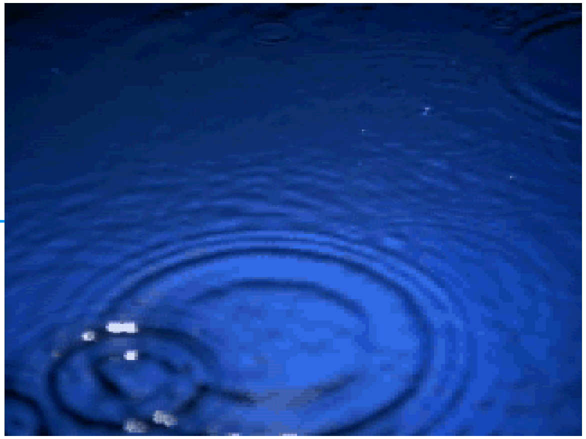
DPR Overview/Requirements



System Requirements Review

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The Precipitation Radar (PR) of the Tropical Rainfall Measuring Mission (TRMM) has demonstrated the accurate rainfall measurement from space.

Capability to observe 3-Dimensional structure of rain

- ✓ First spaceborne precipitation radar.

Accurate observation of radar reflectivity factor (Z)

- ✓ +/- 0.5dB accuracy and stable performance more than 4 years.

Improvement of microwave radiometer algorithm

- ✓ TMI algorithm was improved by the information of PR.

Global Precipitation Measuring is desired.

TRMM/PR to GPM/DPR

Learned from TRMM

- Ability to measure rainfall accurately from space
- Still 20% difference between PR and TMI (Ver. 5)

→ **More accurate observation.**

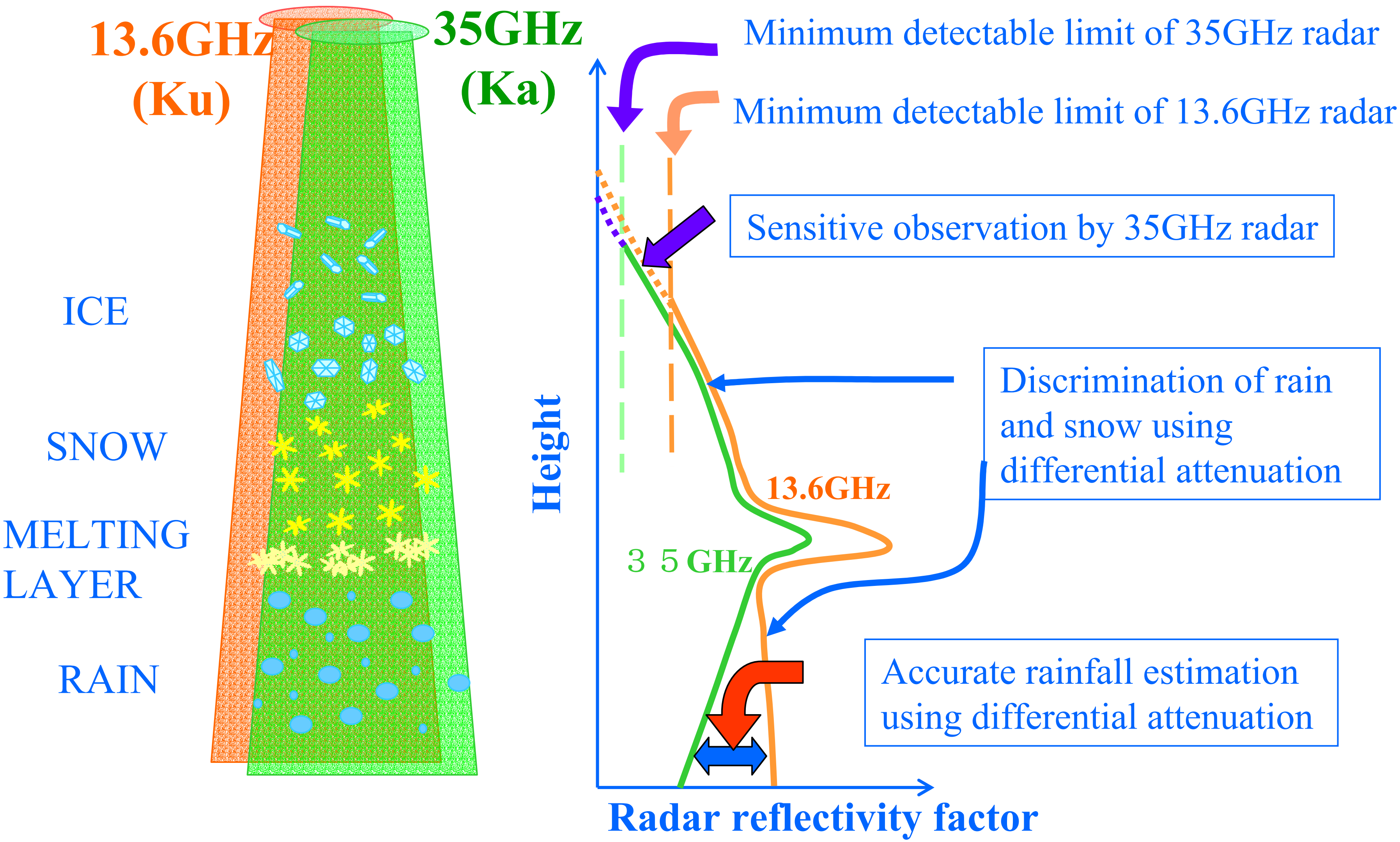
Global precipitation measurement

- Observation of rain/snow in high latitude regions
- Discrimination of rain/snow

→ **More observation parameters.**

→ **DPR**

Dual frequency precipitation radar (DPR)



Advantage of DPR

- ✓ Three-Dimensional observation of global precipitation as same as TRMM/PR.
- ✓ Rain/snow classification by using the differential attenuation between two frequencies.
- ✓ Precise rain rate retrieval using not only Z-value but also information of differential attenuation.

TRMM/PR like product (single frequency)

- ✓ *Vertical profile of precipitation (3-D structure)*
- ✓ *Surface rain map*
- ✓ *Monthly rain map (5deg x 5 deg)*

Dual frequency product

- ✓ *Same as single frequency products with better accuracy*
- ✓ *Drop size distribution (DSD) information*

Requirements to DPR

The requirements to DPR are basically same performance as TRMM/PR, but

Sensitivity

12dBZ(35.5GHz), 17dBZ (13.6GHz)
(0.1-0.2 mm/h) (0.5-0.7mm/h)

Swath

100km (35.5GHz) , 245km (13.6GHz)

Matched beam

Both radar should have same foot print location
(requires good alignment and synchronization)

Tentative Specification of DPR

Item	13.6GHz radar (PR-U)	35.5GHz radar (PR-A)
Antenna Type	Slotted wave-guide	Slotted wave-guide
Scan	Active Phased Array	Active Phased Array
Frequency Band	13.6 GHz = Ku-band	35.55 GHz = Ka-band
Beam Number	49	20
Swath Width	245 km	100km
Pulse Width	1.6 micro sec. (x2)	1.6 micro sec. (x2)
Range Resolution	250 m	250 m/500m
Beam Width	0.7 Deg.	0.7 Deg.
Horizontal Resolution	5 km	5 km
PRF*	2445Hz	2445Hz

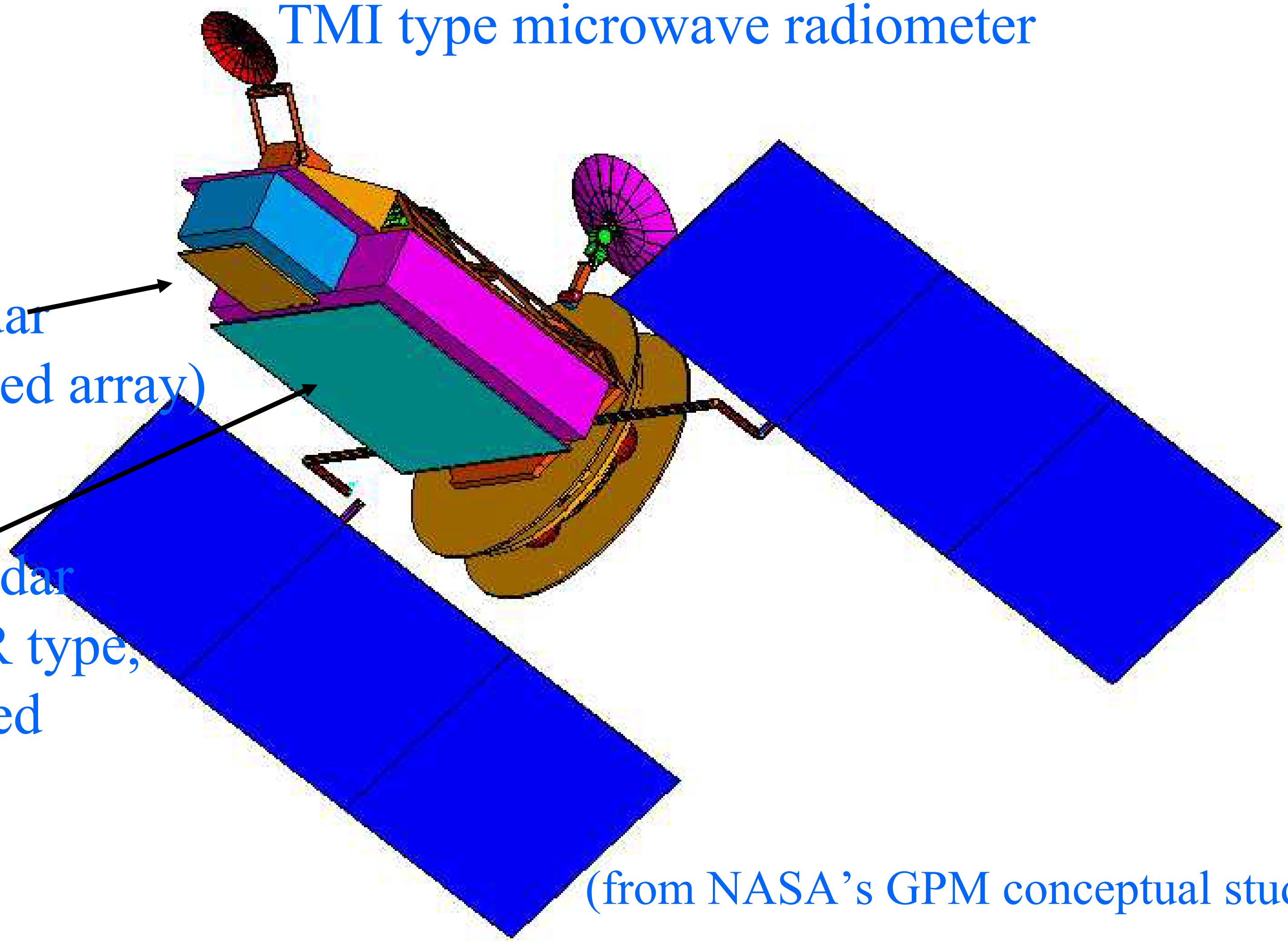
*: variable PRF method is being studied for increase sensitivity.

Specifications of DPR (continued)

Item	13.6GHz radar (PR-U)	35.5GHz radar (PR-A)
Peak Power	1000W	144W
Sensitivity (current estimate)	17dBZ	12dBZ (18dBZ) *
Data Rate	95 kbps	95 kbps
Weight	370 kg	290kg
Power Consumption	320 W	250 W
Size	2.4 ×2.4 ×0.5 m (box)	1.0 ×1.0 ×0.5m (box)

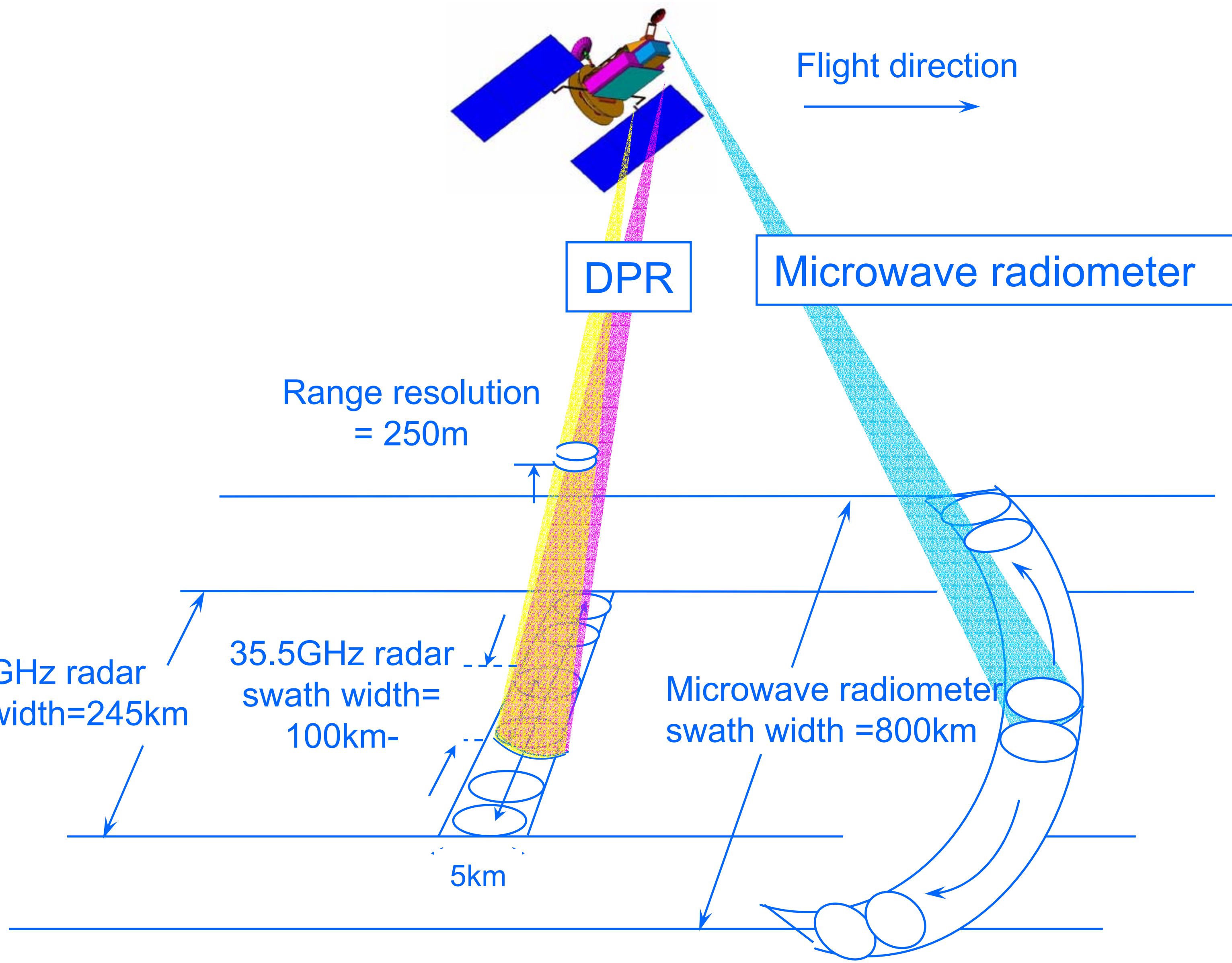
*: 35.5GHz radar is needed to improve sensitivity to satisfy the requirements.

Conceptual image of GPM/Core



(from NASA's GPM conceptual study)

Conceptual image of GPM/Core observation



Electrical interface for DPR

- ***NASDA has experience to use 1553B data bus. TRMM type allocation is assumed.***
- ***GPS data can be delivered via 1553 data bus (time, Lat/Lon, altitude)***
  - *altitude information is essential if DPR requires sampling control.--- reduction of data rate.*
  - *Lat/Lon information is helpful if DPR introduces variable PRF depending on the location.*

Mechanical Interface of DPR

- ***Ka-Ku alignment requirements.***
  - *less than 0.01 – 0.02 degrees along track direction.*
  - *estimated distortion of antenna surface is about 0.1 degrees.*
- ***Radar to S/C interface***
  - *Kinematic mount as same as TRMM/PR*
- ***Alignment of TRMM/PR case***
  - *0.04 degrees across track direction*

Concept of DPR development

Start with TRMM/PR design concept for Ku-band radar.

- ✓ *To save the cost, development term.*

Ku-(13.6GHz), and Ka-(35.5GHz)band radar are independent system.

- ✓ *Effective development and testing.*
- ✓ *Independent thermal design is much simpler than combined system.*

Cooperative development between NASDA and CRL

- ✓ *tentative plan--- 13.6GHz radar (NASDA),*
  35.5GHz radar (RF: CRL, System: NASDA)

GLOBAL PRECIPITATION MEASUREMENT

DPR work items before development phase

	Concept	Need to develop/study	Note
Antenna design	*TRMM/PR type but lighter weight (128 elements)*	*Half thick waveguide slot antenna*	*PR-U, PR-A: completed (2000)*
RF unit design	*T/R module (128 elements)*	*SSPA, PHS, MMIC, MCM, and integration*	*PR-U: trial manufacturing of chip (2002-03)* *PR-A:completed (2001) → T/R module study and BBM. (2002)*
Signal processing unit design	*TRMM/PR type with GPS*	*- variable PRF* *- pulse width* *- onboard processing*	*For better sensitivity and reduction of downlink data.* *(2001-2002)*
Thermal design	*TRMM/PR type*	*Size of radiation panel*	*Depending on the RF unit chip development and DPR operation mode.*
Mechanical design	*TRMM/PR type*	*Alignment between PR-U and PR-A*	*According to "matched beam" requirements. (2001-2002)*

Phase Shifter and SSPA for PR-A

Phase shifter

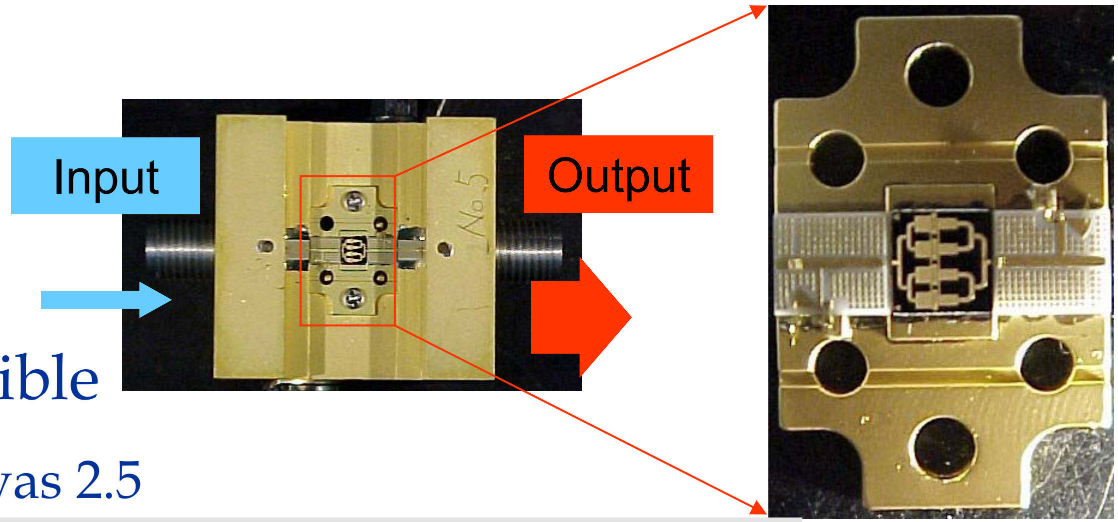
SSPA

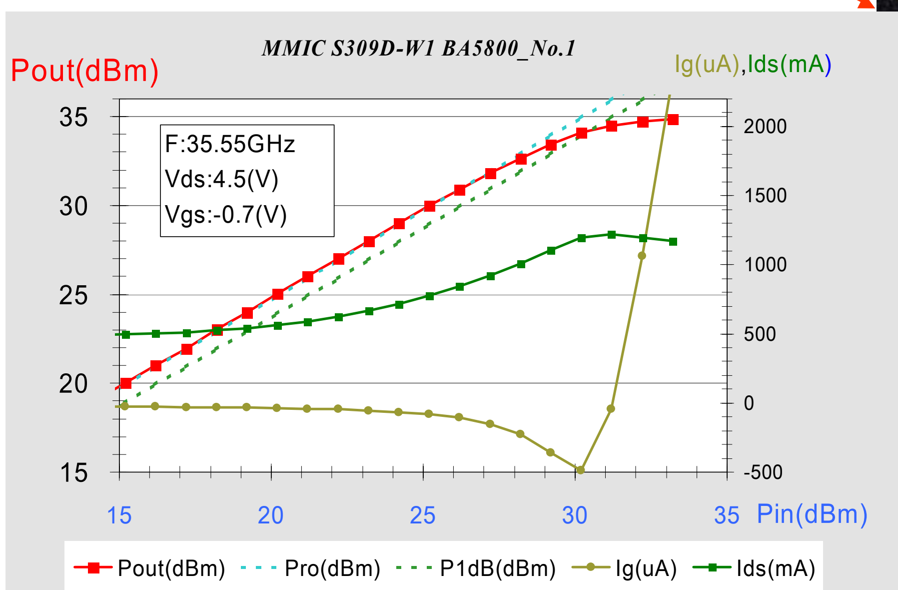
High Power SSPA CHIP for PR-A

4 FET in one chip

3 W/chip is possible

(Previous estimate was 2.5 W)





Reliability of SSPA and Phase Shifter of PR-A

Thermal test

The high temperature DC operating test of SSPA chips and the high temperature reverse biased test of Phase Shifter chips were carried out at 225 and 240 degree Celsius.

Estimated MTTF (mean-time-to-failure)

	Tch = 125℃	Tch = 150℃
SSPA FET	1×10^6 h (=114 years)	1×10^5 h (=11.4 years)
PIN diode PHS	1×10^7 h (=1140 years)	1×10^6 h (=114 years)

Gamma-ray test

The γ-ray irradiation test of PIN diode Phase Shifter was carried out at 1×10^8 [rad] max.

⇨ Sufficient radiation hardness for LEO is qualified.

Sensitivity Calculations of PR-A

- Z (S/N=1 for 1 pulse, res=250 m) = 22.4 dBZ
- Z (S/N=1 for 1 pulse, res=500 m) = 16.4 dBZ

Swath width	N of beams	Obs. Time /beam	N of pulses	Effective S/N(dB)	σ(dB)	3σ S/N(dB)	Min dBZ	Rain (mm/h) Ze=200R^1.6	Min dBZ	Rain (mm/h) Ze=200R^1.6
							Range res. = 250 m		Range res. = 500 m	
5 km	1	714.3 ms	4470	14.0	0.092	-16.3	6.1	0.053	0.1	0.004
40 km	8	89.3 ms	558	9.5	0.256	-11.1	11.3	0.185	5.3	0.078
100 km	20	35.7 ms	224	7.5	0.397	-8.5	13.9	0.270	7.9	0.114
245 km	49	14.6 ms	68	5.0	0.696	-4.4	18.0	0.486	12.0	0.205

(For the matched beam condition, refer to SW=245 km.)
(Number of noise samples is 4 x N)

Assumptions:

- H = 400 km (ΔH=10 km)
- Beam width = 0.71 degree
- Range res. = 250 m/500 m
- Log detection
- 2-freq. agility
- Tx power = 144 W
- Rx noise = -110.0 dBm
- Feed Loss = 1.5 dB
- Filter Loss = 1.3 dB

Sensitivity issue (PR-A)

Requirement for Ka-band radar sensitivity is several dB better than current estimate.

More powerful SSPA --- improves 1-2 dB
- ✓ *causes heavier mass, more power*

Range resolution to be 500m --- improves 6dB
- ✓ *causes high duty, degradation of range resolution*

Variable PRF ---improves up to 2dB
- ✓ *causes high duty, needs more study.*

3- or 4-frequency agility --- 0.9 or 1.5 dB improvement
- – *Higher power consumption and heat release*

3-bit pulse compression --- 4.7 dB improvement
- ✓ *Range side lobe in +/- 250 m*

Uniform Tx antenna weighting --- +2 dB? improvement
- ✓ *No increase in power consumption*
- ✓ *unmatched with Ku pattern*

Fixed PRF vs Variable PRF: 100-km Swath Case

<table>
<tr><th rowspan="2">Satellite Altitude (km)</th><th>Fixed PRF</th><th colspan="3">Variable PRF #1</th><th>Variable PRF #2 (*1)</th></tr>
<tr><th>after 5 pulses</th><th>after 7 pulses</th><th>after 7 pulses</th><th>after 7 pulses</th><th>after 12 pulses</th></tr>
<tr><td>380</td><td rowspan="5">2089 Hz</td><td></td><td rowspan="3">2923 Hz</td><td rowspan="2"></td><td>5003 Hz</td></tr>
<tr><td>390</td><td rowspan="3">2848 Hz</td><td>4872 Hz</td></tr>
<tr><td>400</td><td rowspan="3">2778 Hz</td><td>4748 Hz</td></tr>
<tr><td>410</td><td rowspan="2"></td><td>4630 Hz</td></tr>
<tr><td>420</td><td></td><td>4518 Hz
4880 Hz (*2)</td></tr>
</table>

(*1) Altitude margin < 3 km, rain echo < 15 km, mirror echo < 5 km,
Scan angle < 7.5 deg., beam error < 0.4 deg.,
Freq. Agility = 2, Tx<->Rx = 15.58 ms

(*2) After 13-pulses

Onboard processing for data rate reduction

	Data rate (kbps/radar)	GPS
Surface tracking (same as TRMM) To determine over-sample range. It may be possible without GPS data.	***95***	(○)
Sampling range control To extract data of appropriate range using GPS data	***60 *1*** ***(115*2)***	○
Rain/No rain classification Only rain detected beam and surface echo are downlinked.	***45*3***	○

*1: Sample window is 23km.

*2: Full over-sample with sample window of 23km.

*3: Full over-sample, surface echo sample using 30 range bins, and 10% of rain probability.

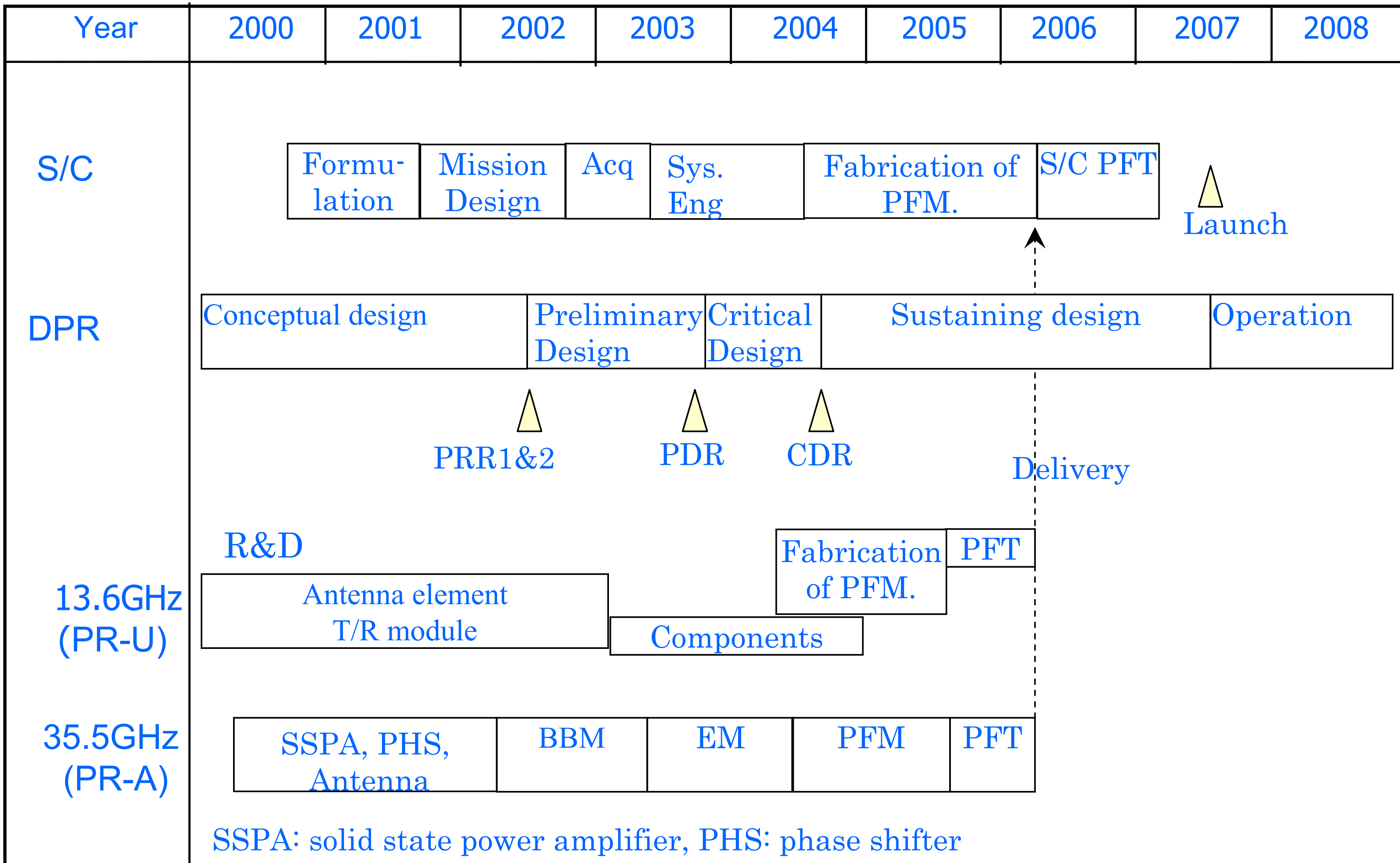
Matched Beam --- alignment issue

- ***Pointing accuracy for matched beam.***
  - *less than 0.05 degrees.*
- ***Estimated distortion of antenna is about 0.1 degrees.***
  - *DPR needs to adjust alignment in the orbit.*
    - *Shift the observation timing?*
    - *Mechanical adjustment? --- Not realistic.*
- ***Post-launch checkout.***
  - *Active radar calibrator (ARC) experiment from ground to know the alignment offset.*
- ***Concept for realizing matched beam.***
  - *Across track direction : adjust the beam direction changing Phase shifter control.*
  - *Along track direction : set delay for one radar system.*

Beam Matching

- *Dimensions and shape*
  - ***Same design for Ku and Ka antennas***
- *Cross-track alignment*
  - ***Granularity of 5-bit Phase shifter:***
    - *Res. = 2.4 m* $(\langle Dq\rangle = q_w/(2^{(5-1)}x128) = q_w/2048)$
- *Along-track alignment*
  - ***Hardware alignment (not adjustable)***
    - *max. error: 0.02 deg=140 m*
  - ***Pulse timing, 1 PRT = 0.5 ms = 3.5 m***
- *Scan direction*
  - ***Hardware alignment (not adjustable)***
    - *max. error: 0.02 deg=17 m at scan edge*

Development schedule (tentative)



Work plan for 2002

- **PR-U : Trial manufacturing key ICs of SSPA and PHS**
- **PR-A : BBM design and manufacturing**
  - Designing of T/R module
- **Detailed system design for radar control**
  - Detailed design of beam matching technique
  - Further examination of variable PRF
  - On-board control logic & signal processing
  - Further examination of Antenna pattern with uniform weight for Tx
- **Algorithm development**
  - dual frequency method.
- **Examination of verification methods**
  - beam matching, variable PRF, external calibration