

# HIGH-SPEED DOWNLINK COMMUNICATIONS WITH HUNDREDS Mbps FROM 50kg CLASS SMALL SATELLITES

**Hirobumi Saito**

Japan Aerospace Exploration Agency (JAXA),  
Institute of Space and Astronautical Science (ISAS)

Naohiko Iwakiri, Atsushi Tomiki, Takahide Mizuno, Hiromi Watanabe,  
Tomoya Fukami, Osamu Shigeta, Hitoshi Nunomura, Yasuaki Kanda,  
Kaname Kojima, Takahiro Shinke, and Toshiki Kumazawa

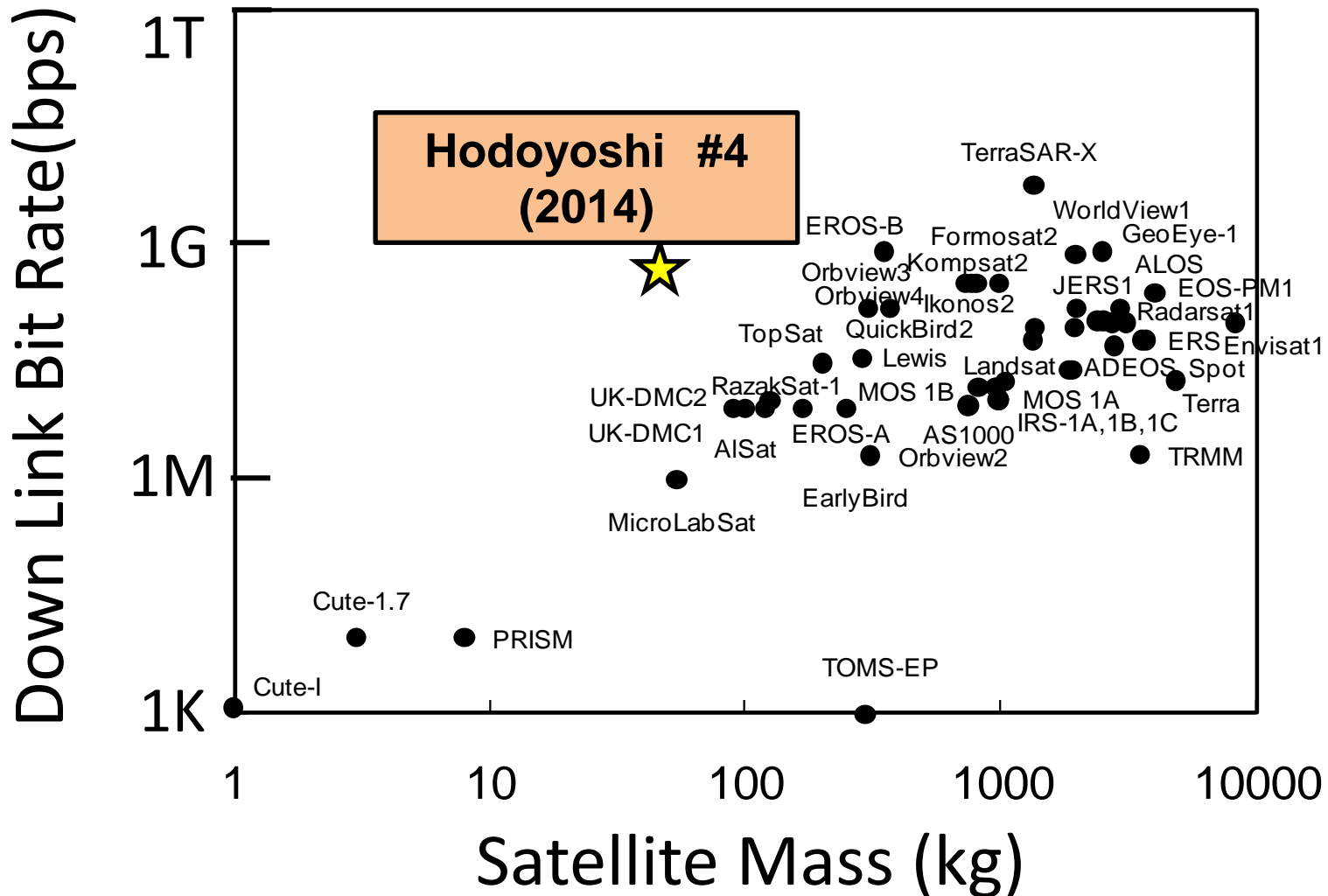
# Contents

1. Purpose : 320Mbps down link for small sat
2. Onboard segment: high efficiency transmitter.  
small antenna
3. Ground segment : 3.8m S/X band antenna  
powerful receiver
4. Total simulation : SPW software + link calculation
5. On-orbit demonstration : 2014 with 50kg sat.

# Limits of Small Satellites for Earth Observations

- Mass Limit (<100kg), Power Limit (<100W)
  - Telescope Resolution (5m vs. 0.5m)
  - Down link Speed (10Mbps vs. 800Mbps)
- What is the Bottleneck of Down Link Speed ?
  - Power !

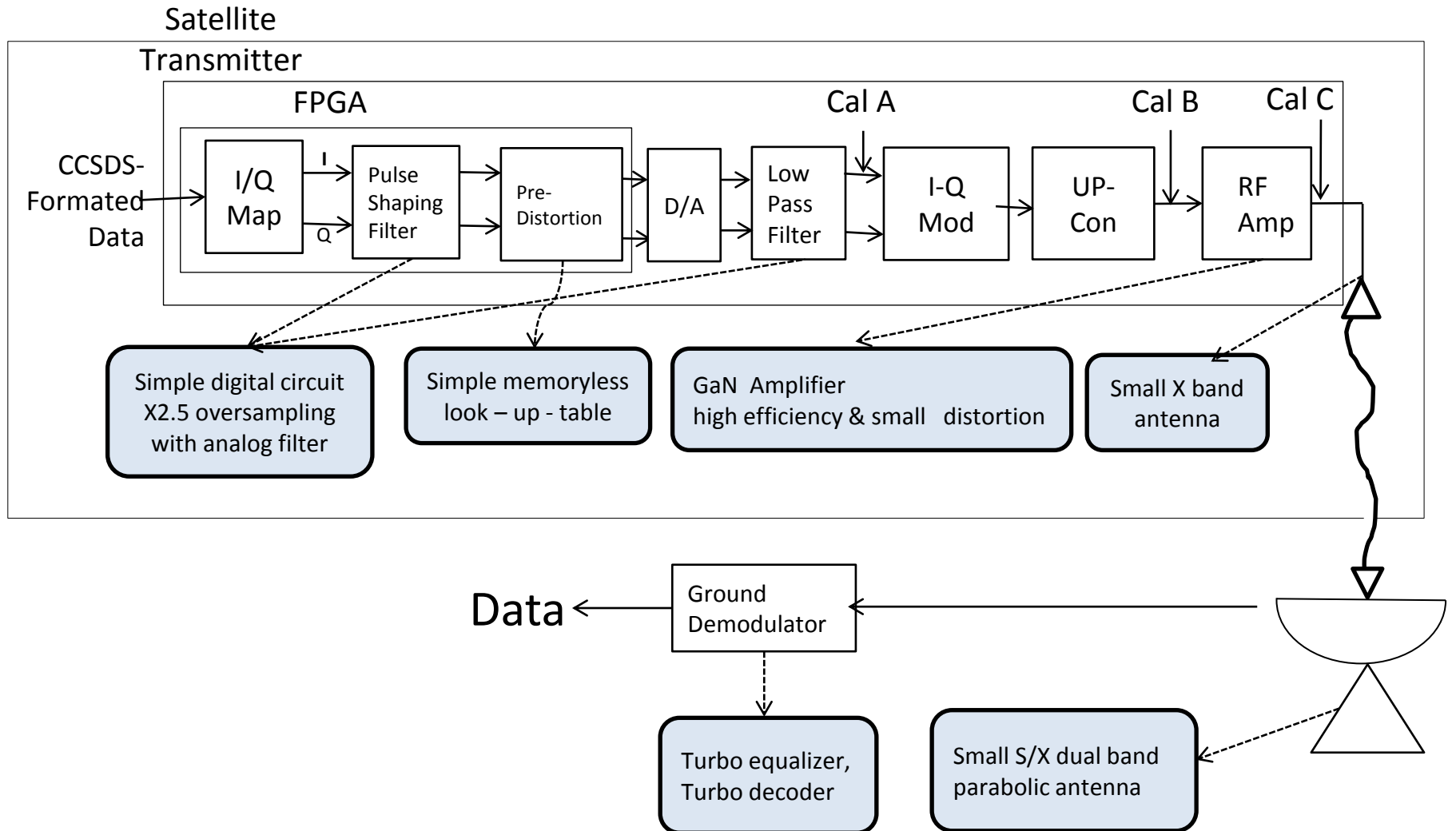
# Down link bit rate VS. satellite mass for low earth orbit.



# High Speed Down Link for Small Sat

- Purpose of This Research :  
High-speed Down Link System  
with Low Power Consumption
- Goal
  - 50kg Sat @600km orbit
  - DC power <20W, 320Mbps
  - Small Ground Antenna < 4m

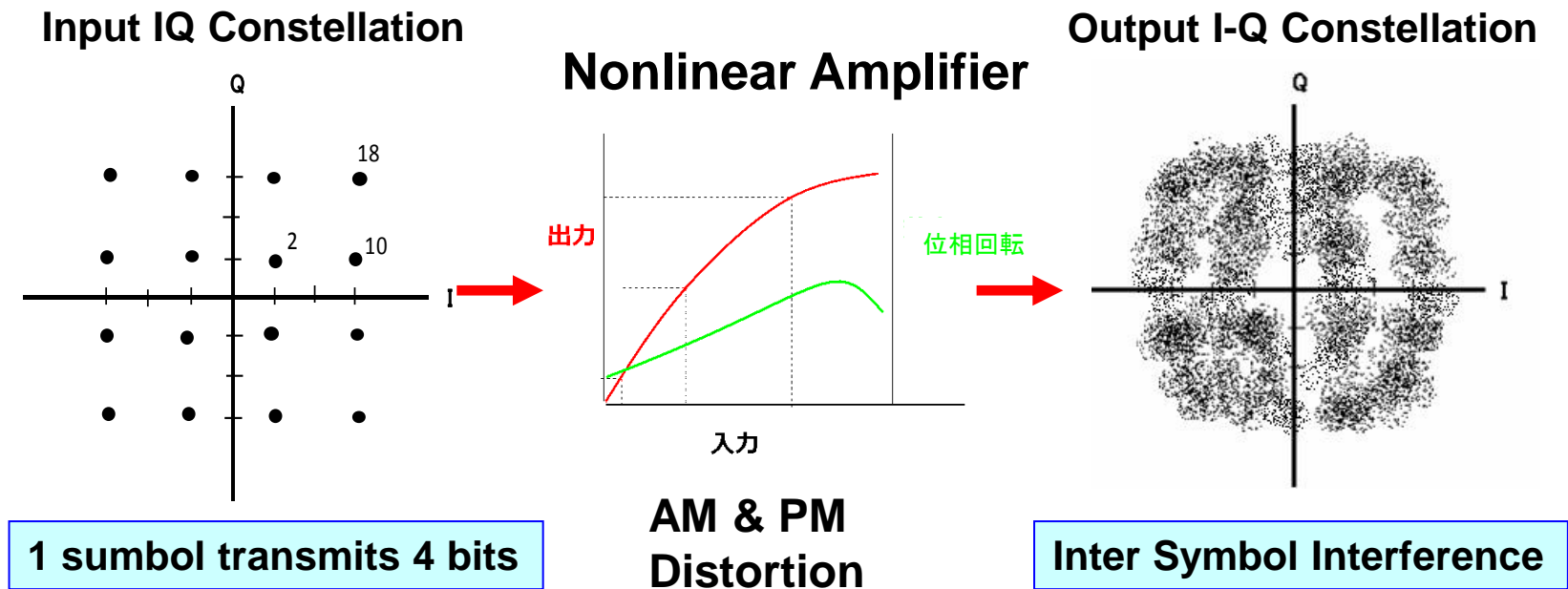
# System block diagram of high-data-rate downlink.



# Performance of High - Data - Rate Down Link

Instruments	Mass (g)	Power (W)	Remarks
<b>On-board</b>			
Transmitter	1330	18	16QAM, 348Mbps GaN Power Amp.
Antenna			
MGA	69	0	14.6 dBi
Iso-flux	150	0	5dBi(60°), -2dBi(0°)
<b>Ground Station</b>			
Antenna	3.8m Dia. S/X Cassegrain 48dBi(X), 36dBi(S)		
Demodulator	100Msps, (348-144Mbps), 16QAM, QPSK SCCC Turbo Equalizer CCSDS 131.0.		

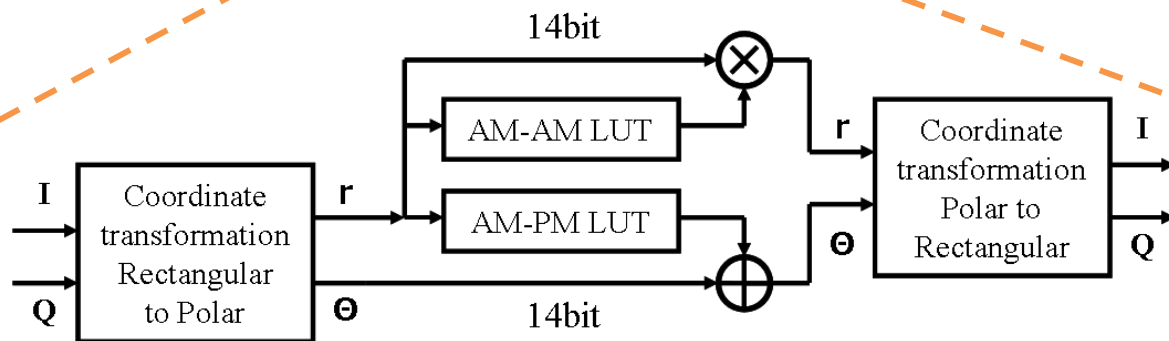
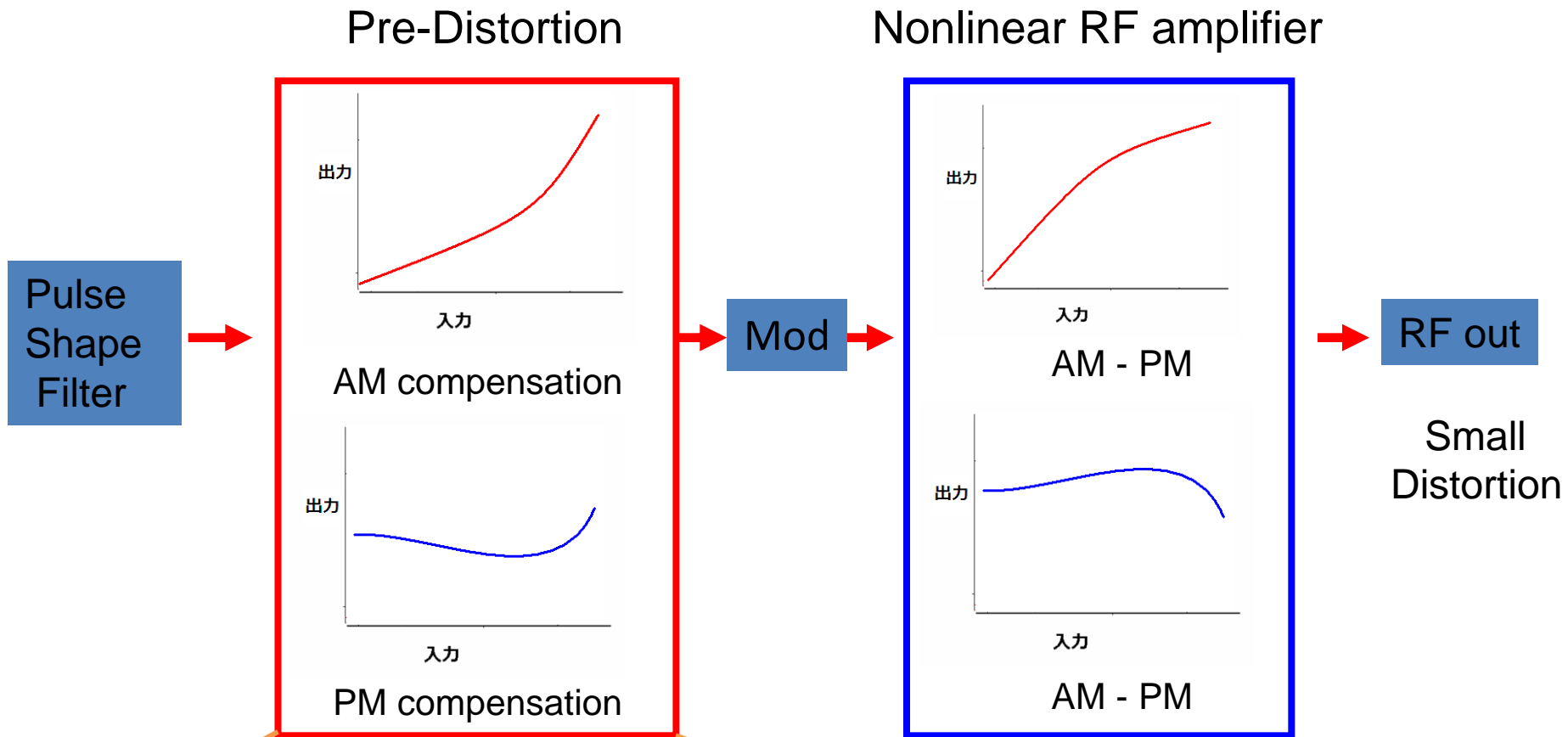
# High-Speed 16QAM Down Link with Nonlinear Amplifier



**High efficiency RF amplifier may degrade bit error rate**



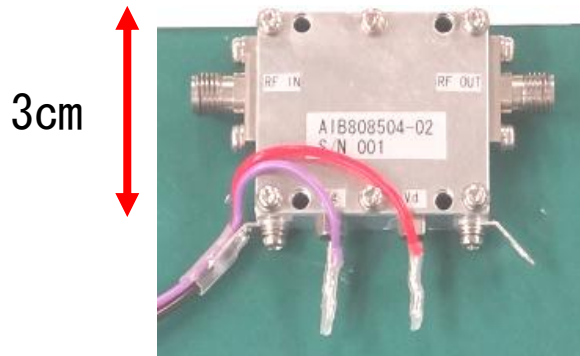
# Digital Pre-distortion compensates Nonlinearity



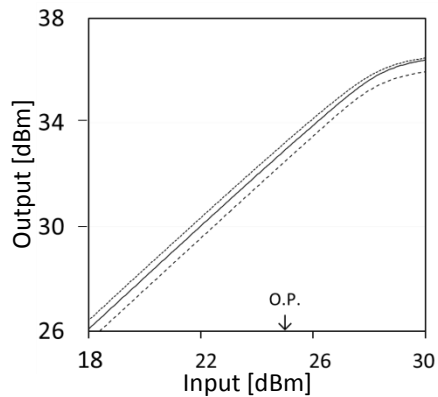
# X Band Power Amplifiers

Amplifier	GaAs AB	GaN AB	GaN F
Maximum Power	38dBm	37dBm	36dBm
Maximum Gain	10dB	11dB	12dB
Maximum PAE	37%	46%	60%
PAE at 3dB OBO	23%	36%	38%
Maximum Phase Shift	10°	-2°	-34°

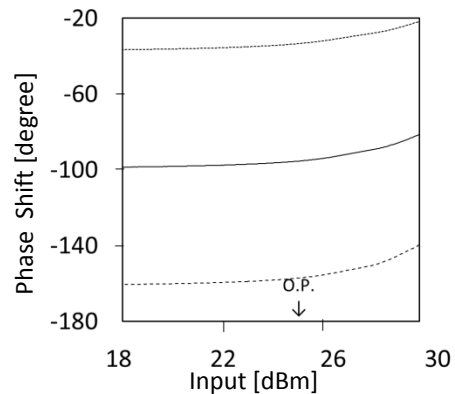
Newly Developed 2W **GaN HEMT AB Class**



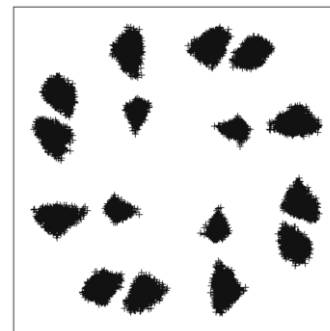
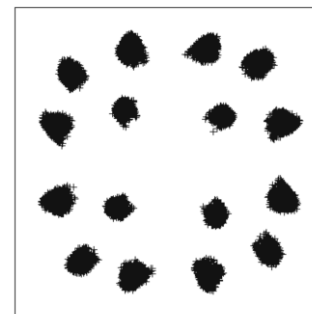
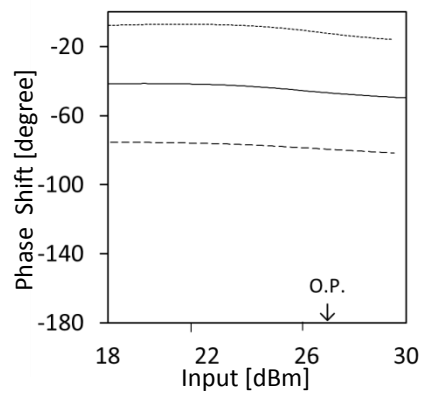
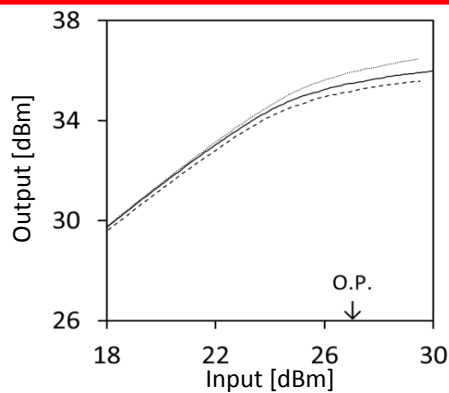
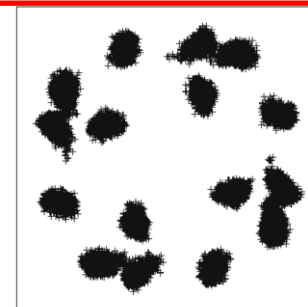
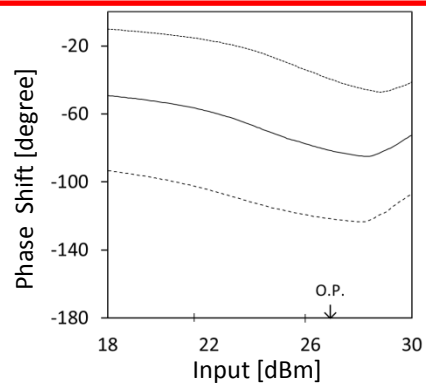
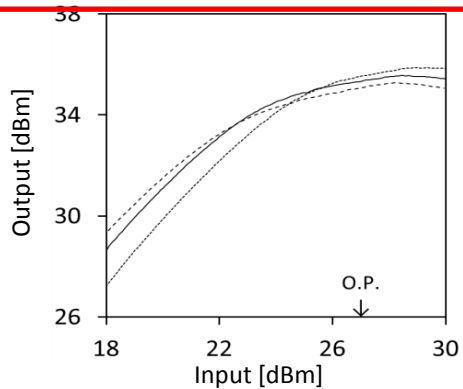
AM/AM



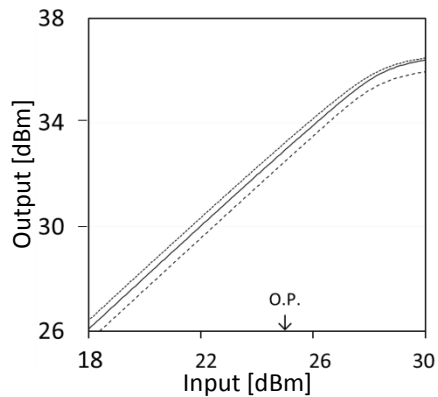
AM/PM



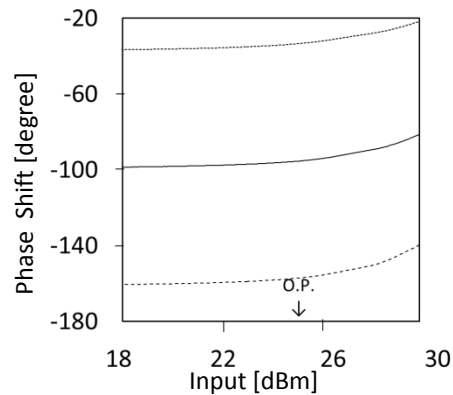
IQ Constellation

Without  
Pre-distortionGaAs  
(AB)GaN  
(AB)GaN  
(F)

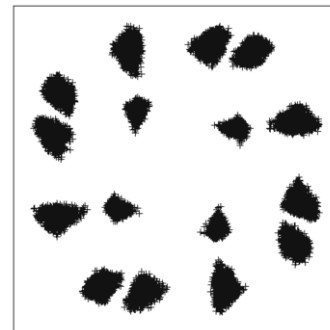
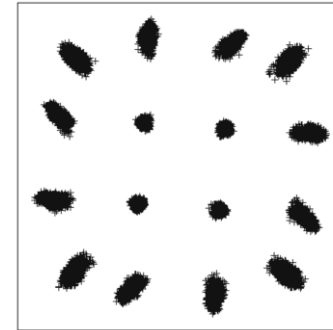
AM/AM



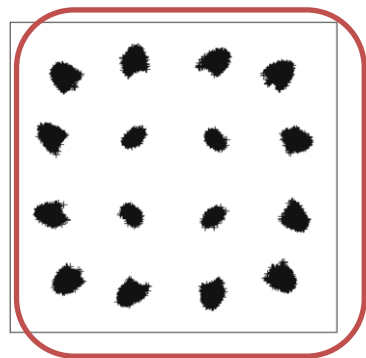
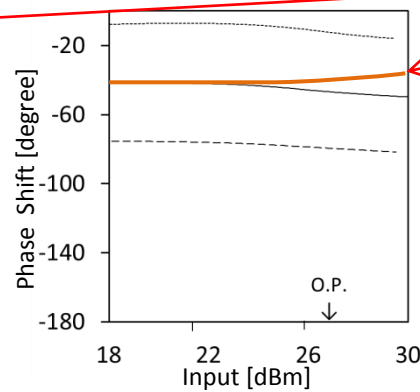
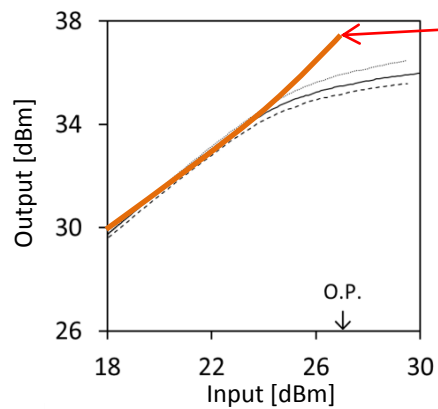
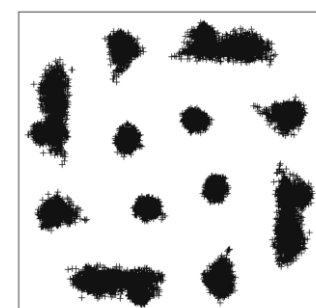
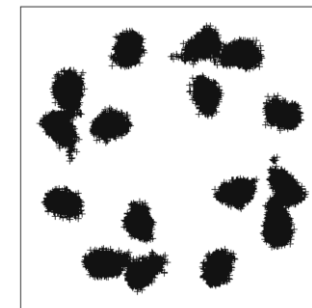
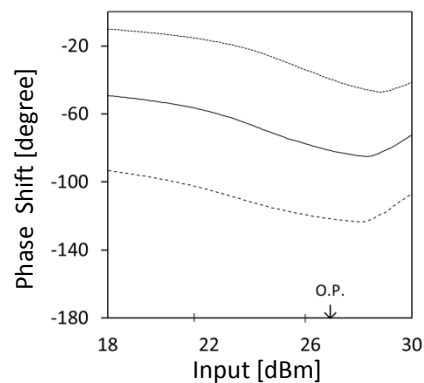
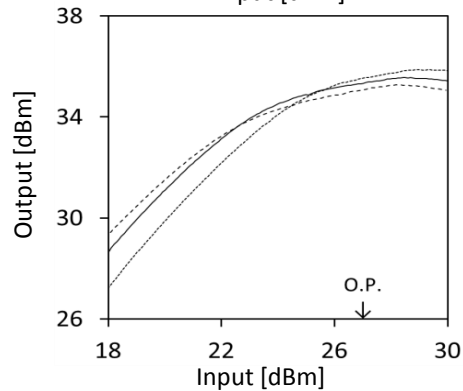
AM/PM



IQ Constellation

Without  
Pre-distortionWith  
Pre-distortion

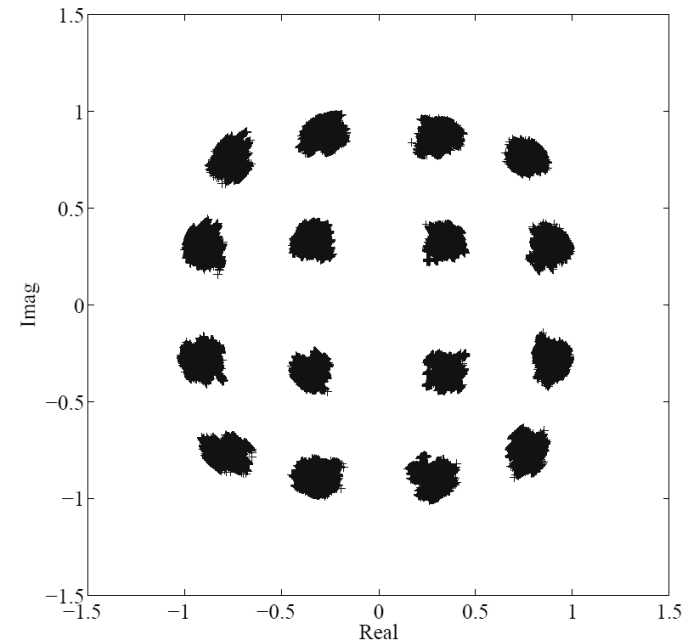
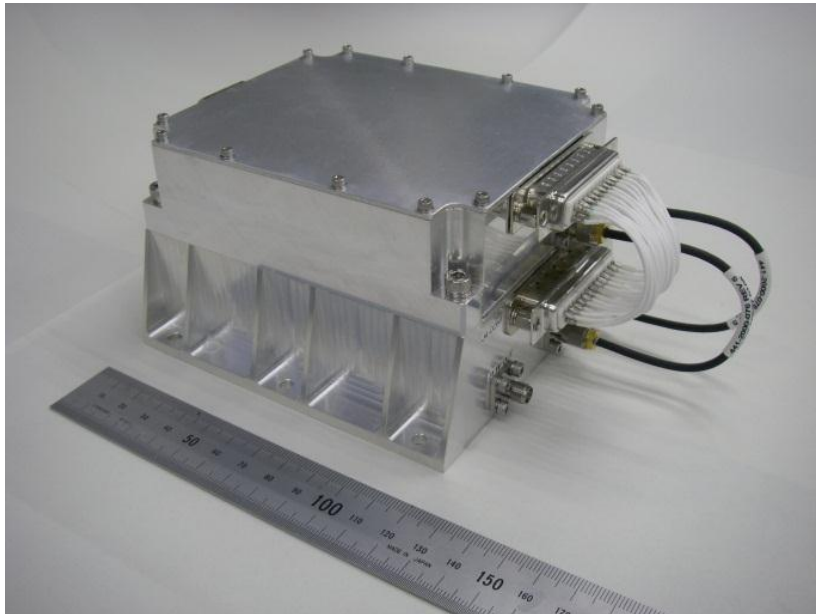
Pre-distortion

GaAs  
(A)GaN  
(AB)GaN  
(F)

# EM of 348 Mbps Transmitter

1330g, 18WDC, 16QAM

measured I-Q map  
w/o pre-distortion



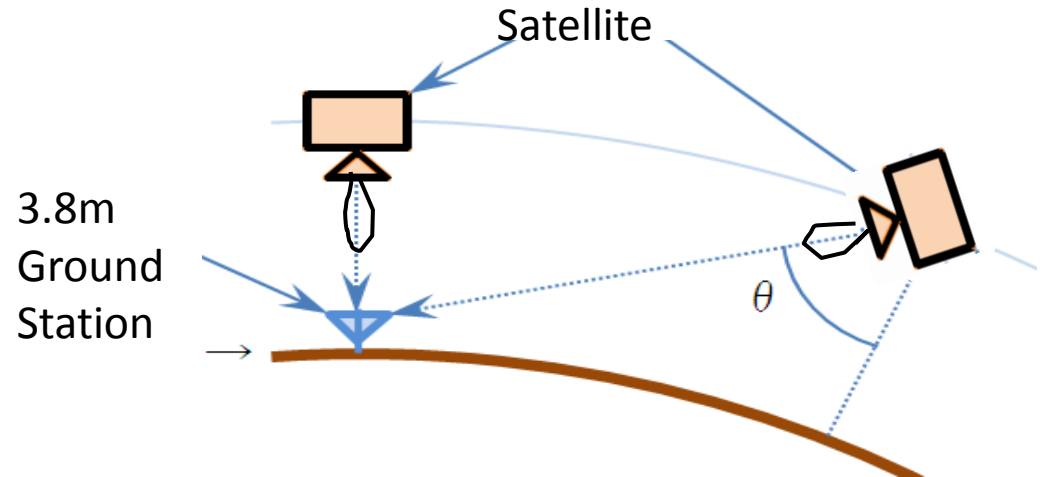
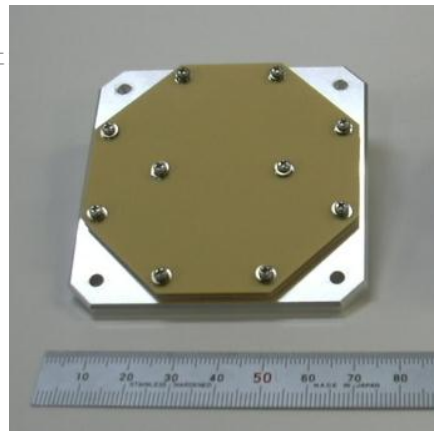
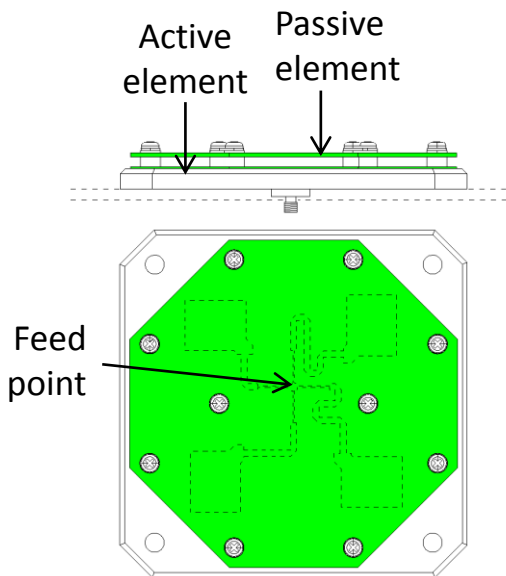
Pre-distortion will be  
installed soon

# Onboard Small Antenna

## Body-Fixed Medium Gain Antenna

14 dBi, 68g

14 dBi, 68g, 7x7cm



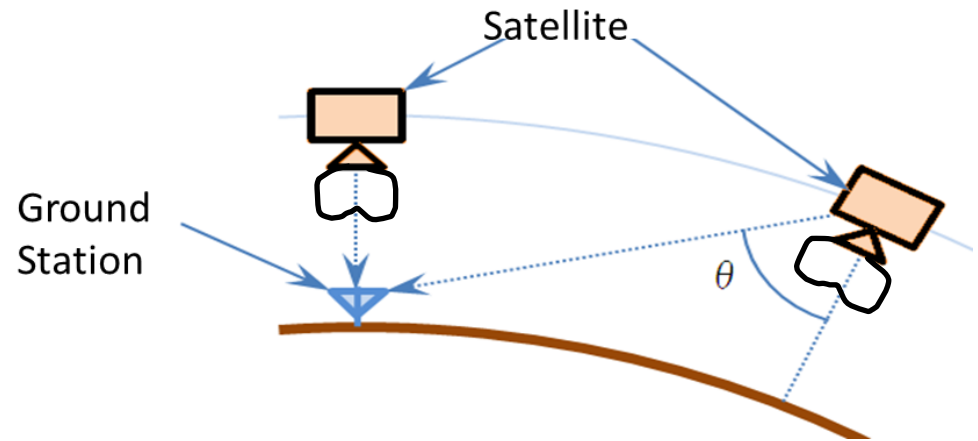
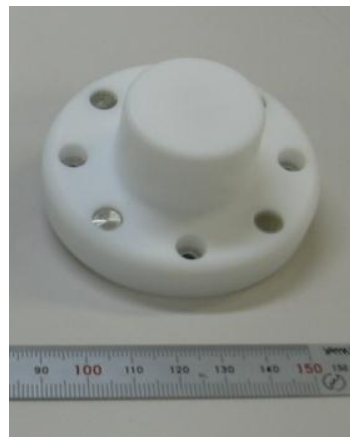
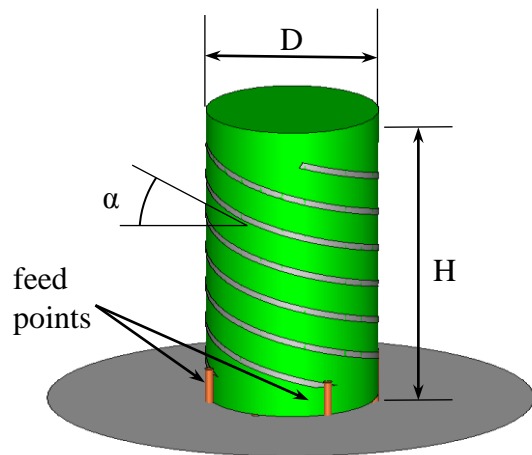
For **320Mbps** high bit rate mode,  
Satellite points earth station

# Onboard Small Antenna

## Body-Fixed Iso-flux Antenna

5dBi max, 150g

quadrafilar helix  
150g, D=10mm, H=20mm



For Earth-Pointing Satellite,  
Antenna pattern compensates  
range variation

# Ground Antenna

## 3.8m Ground Antenna for S / X Band

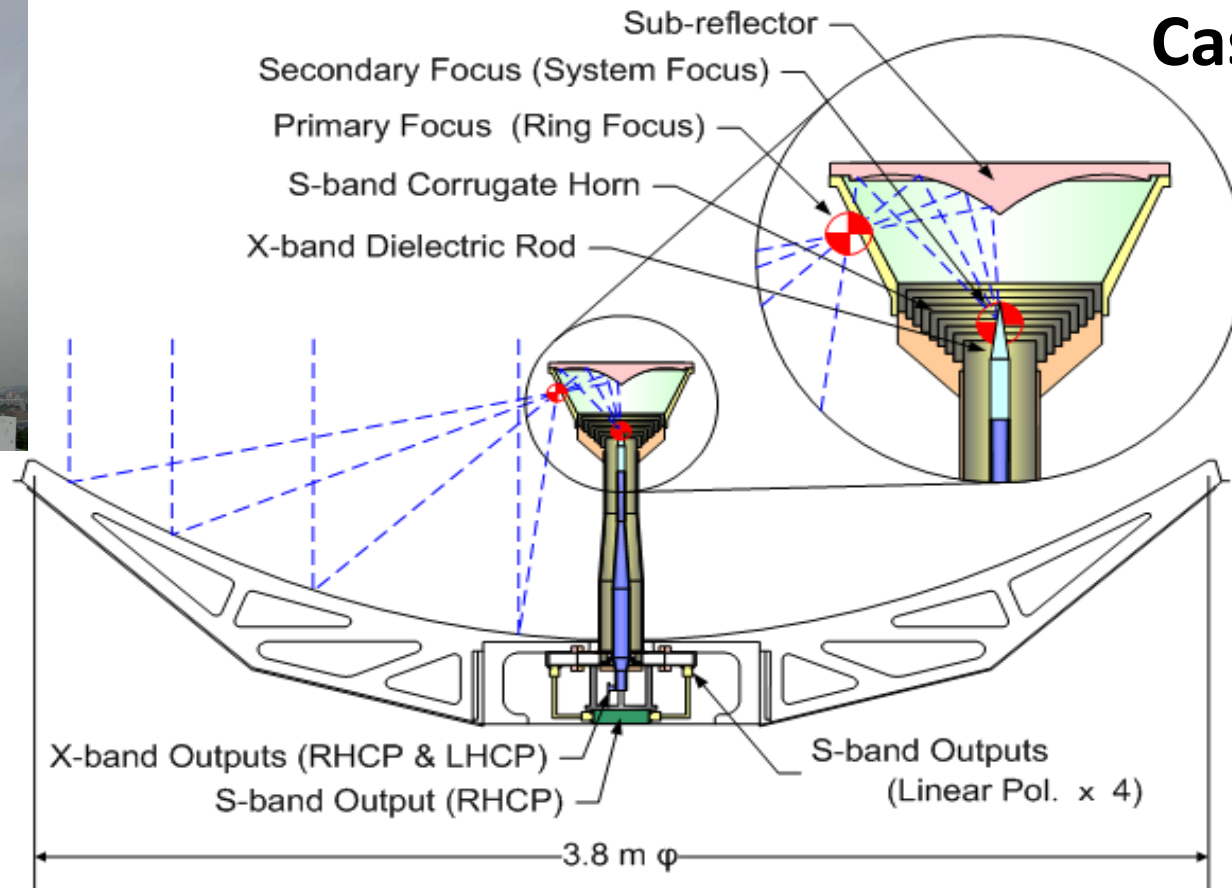
S band : Telemetry & Command

X band : Mission Data Down Link (320Mbps)

Ring-Focus  
**Cassegrain**

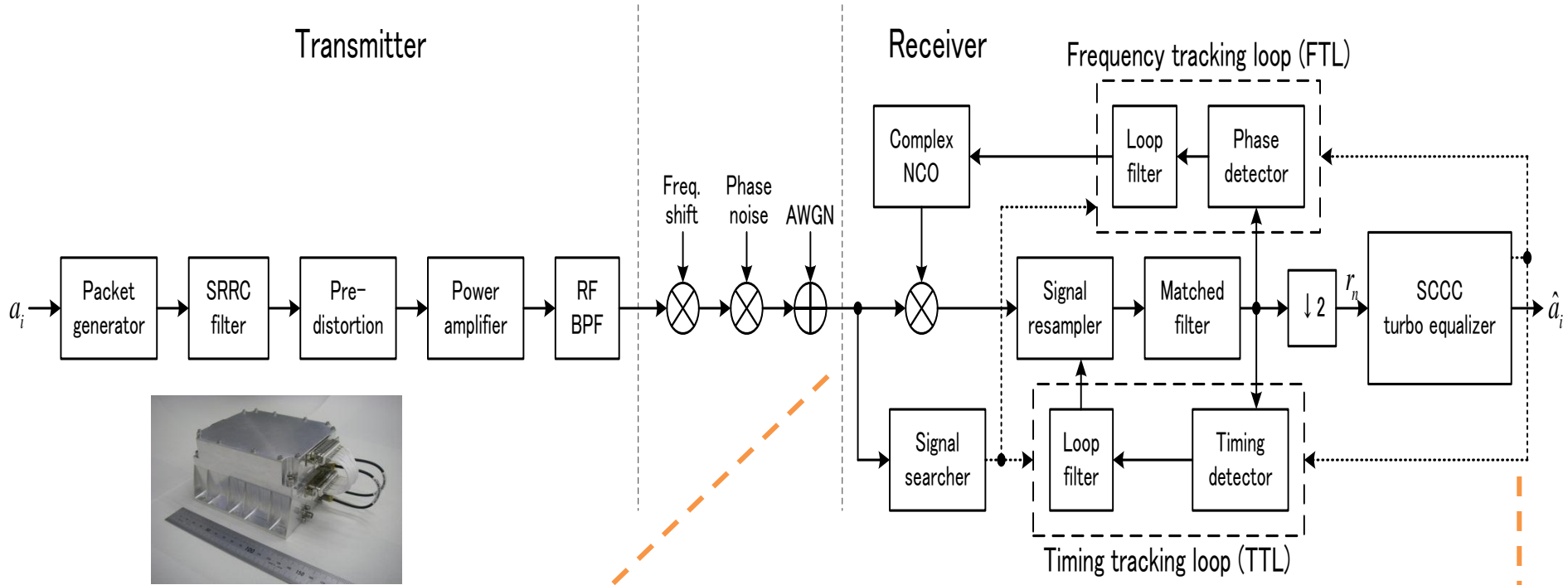


(3m S band)





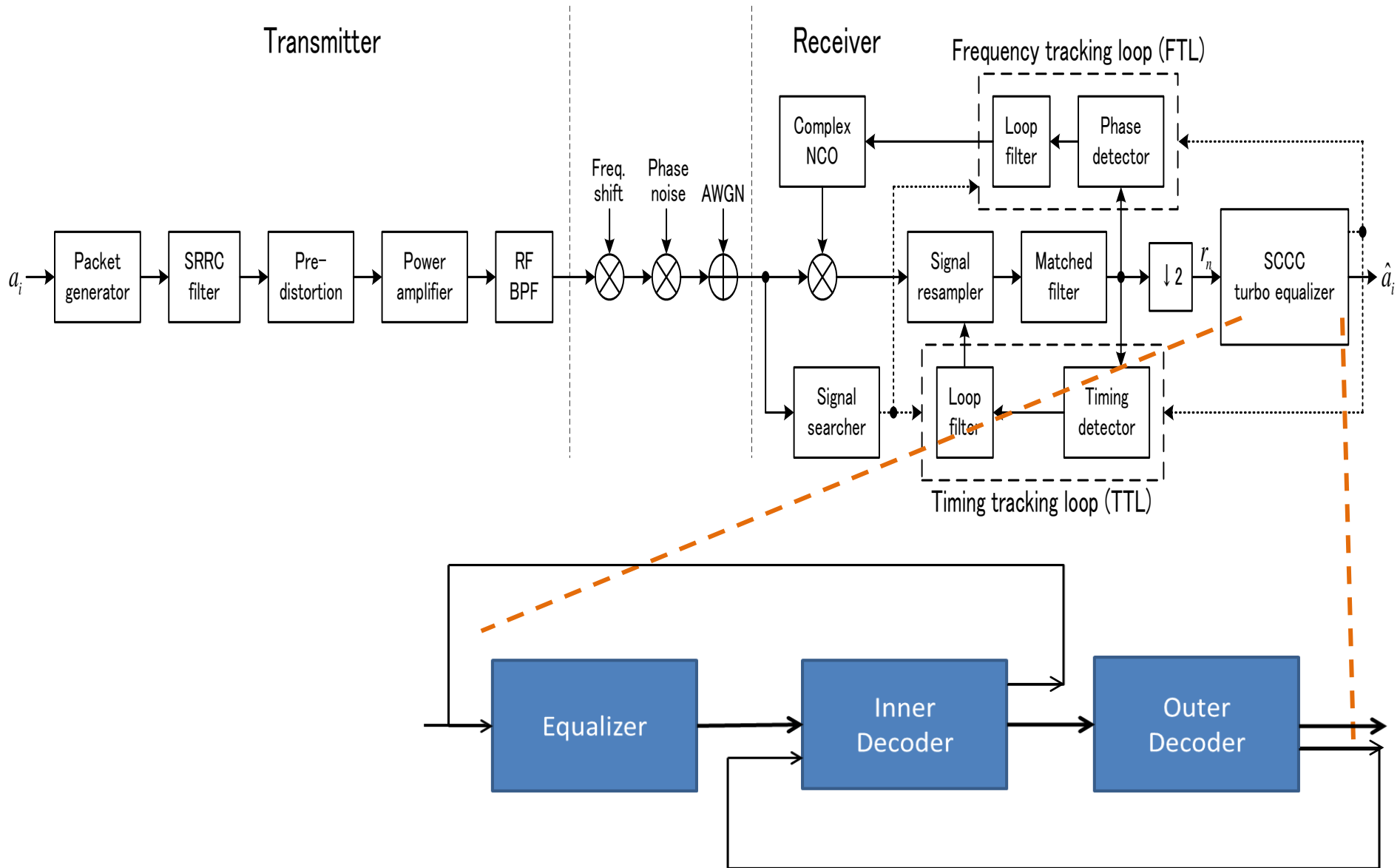
# Block diagram of high-data-rate downlink and ground receiver



Developing 400Mbps  
16QAM ground receiver

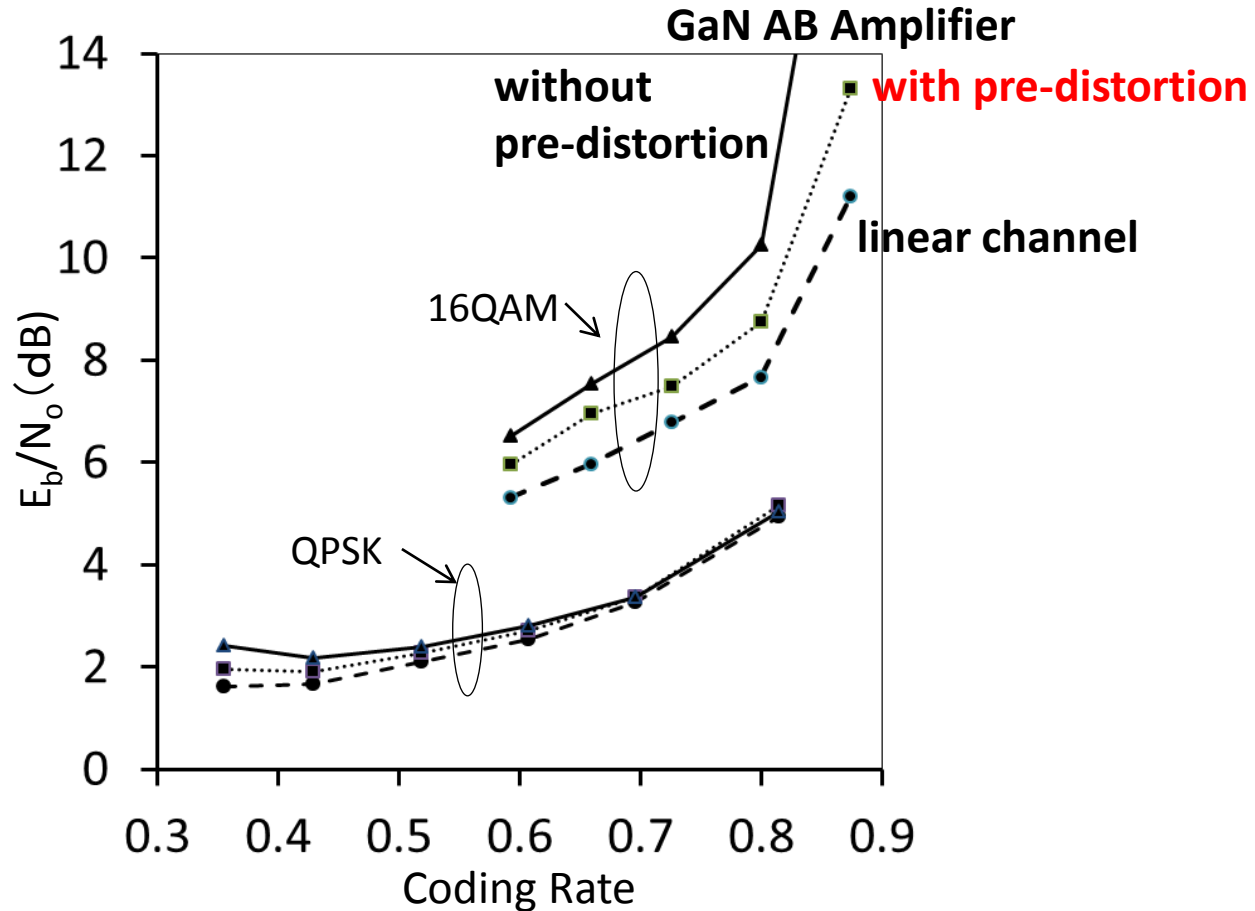


# Block diagram of high-data-rate downlink and ground receiver



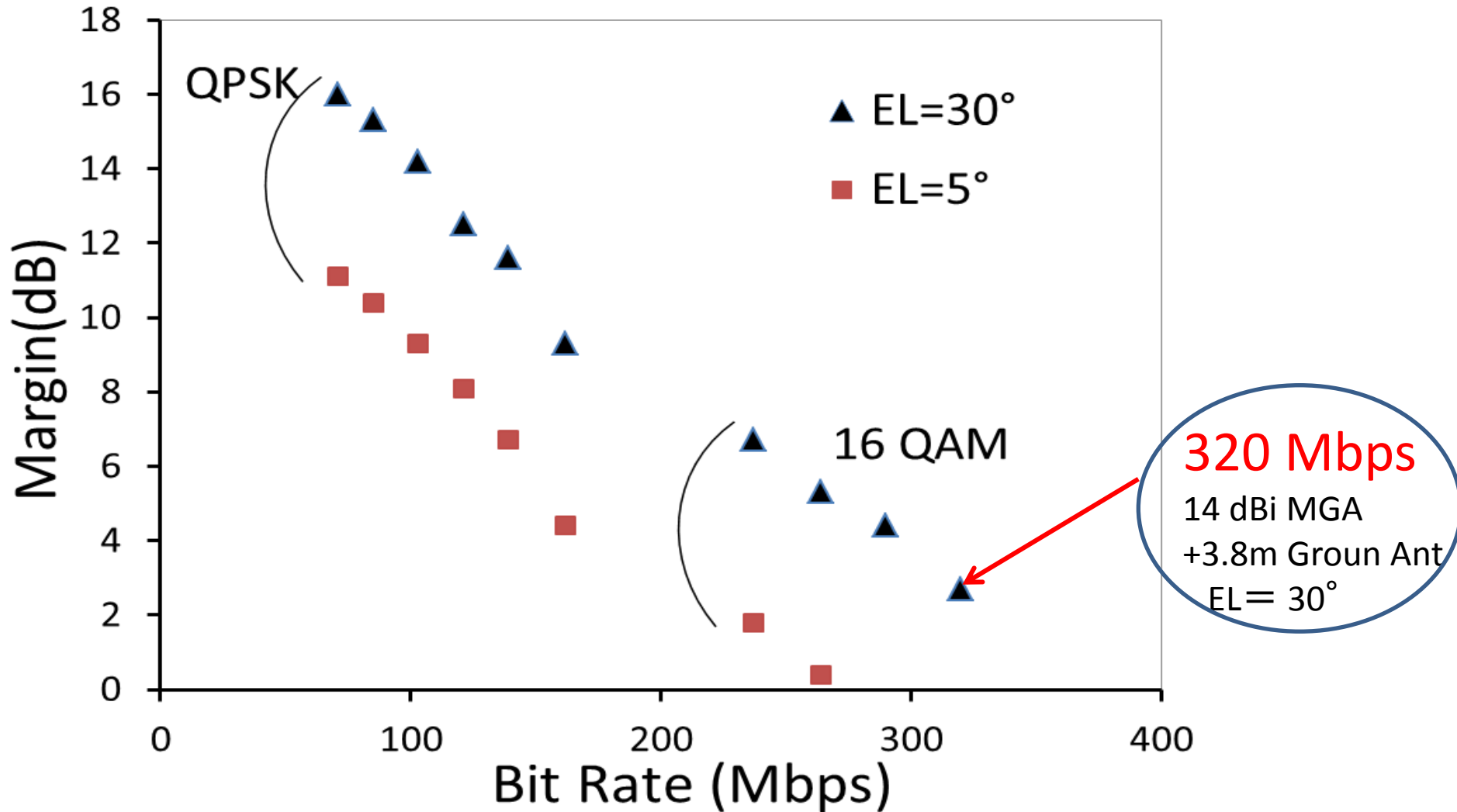
# Simulation

## Required $E_b/N_0$ for BER = $10^{-6}$



CCSDS 131.0 SCCC

# Link margin of high-data-rate down (2W GaN HEMT of AB class with pre-distortion)



# Project Schedule

## Onboard Transmitter

'12 Aug-Oct T EM test

Now !



'13 Feb-April FM test

'13 May FM system test

## Ground Antenna

'13 March Complete

## Ground Receiver

'12 Dec. First test

'13 March Complete ?

## Hodoyoshi -#4 (60kg) Launch

'13 Dec. by Dnepr

Goal !



'14 Demonstration 320Mbps 16QAM test on orbit

# Conclusions

1. Developing **320Mbps 16QAM** down link for **50kg** satellite.
2. Power-efficient transmitter  
(GaN HEMT amp with predistortion)  
small antenna (MGA, isoflux)
3. Small ground antenna,  
powerful receiver (turbo equalizer & decoding)
4. On-board demonstration **in 2014 with 50kg sat.**