SSC13-II-2

300 Mbps Downlink Communications from 50kg Class Small Satellites

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Contents

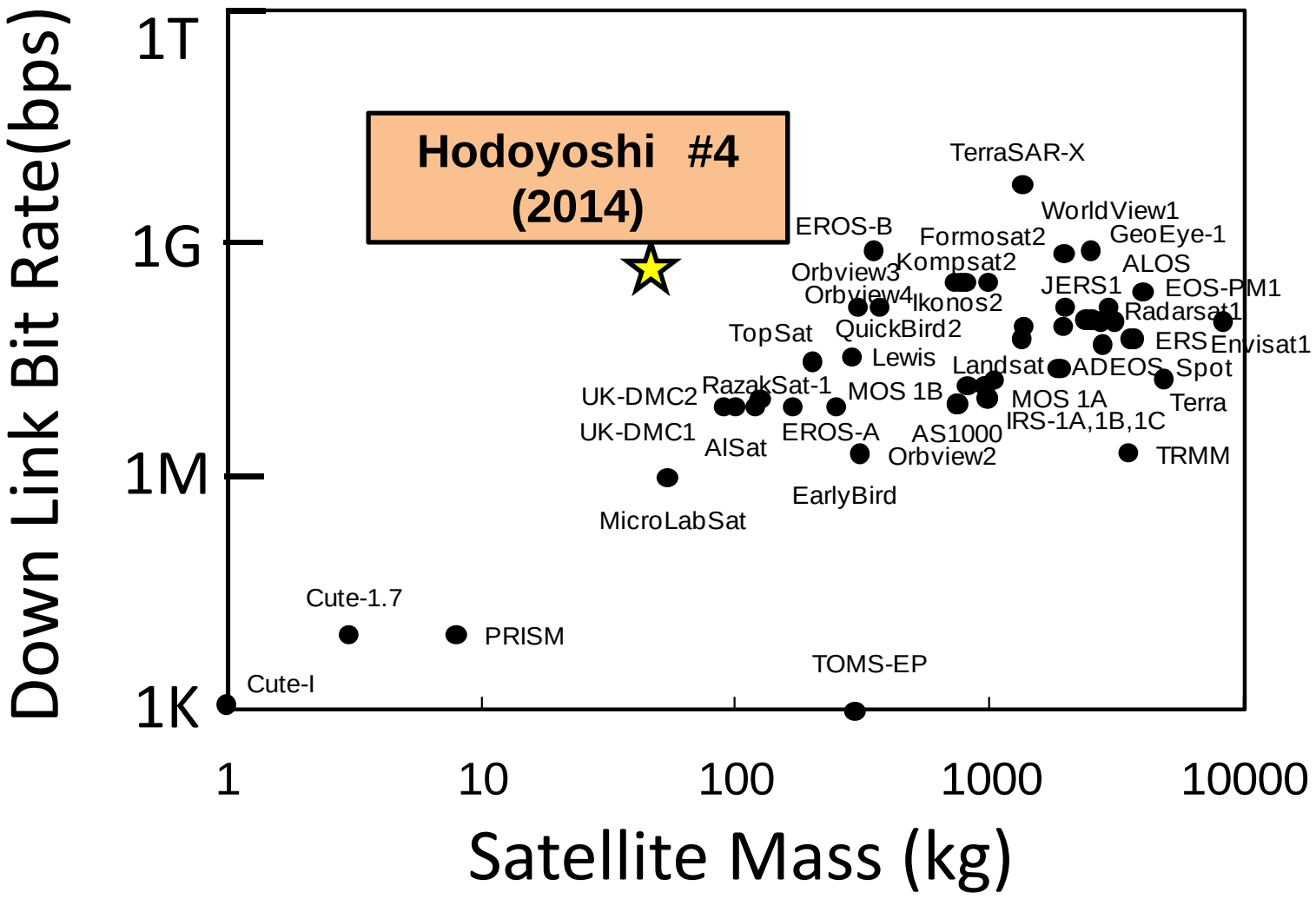
1. Purpose : 320Mbps down link for small sat
2. Onboard segment: high effiency transmitter.
   small antenna
3. Ground segment : 3.8m S/X band antenna
   powerful receiver
4. Total simulation : SPW software + link calculation
5. EM test finished. FM maunfacturing now.
6. On-orbit demonstration : 2014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

Limits of Small Satellites for Earth Observations

- Mass Limit（<100kg）, Power Limit (<100W)
  - Sensor 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

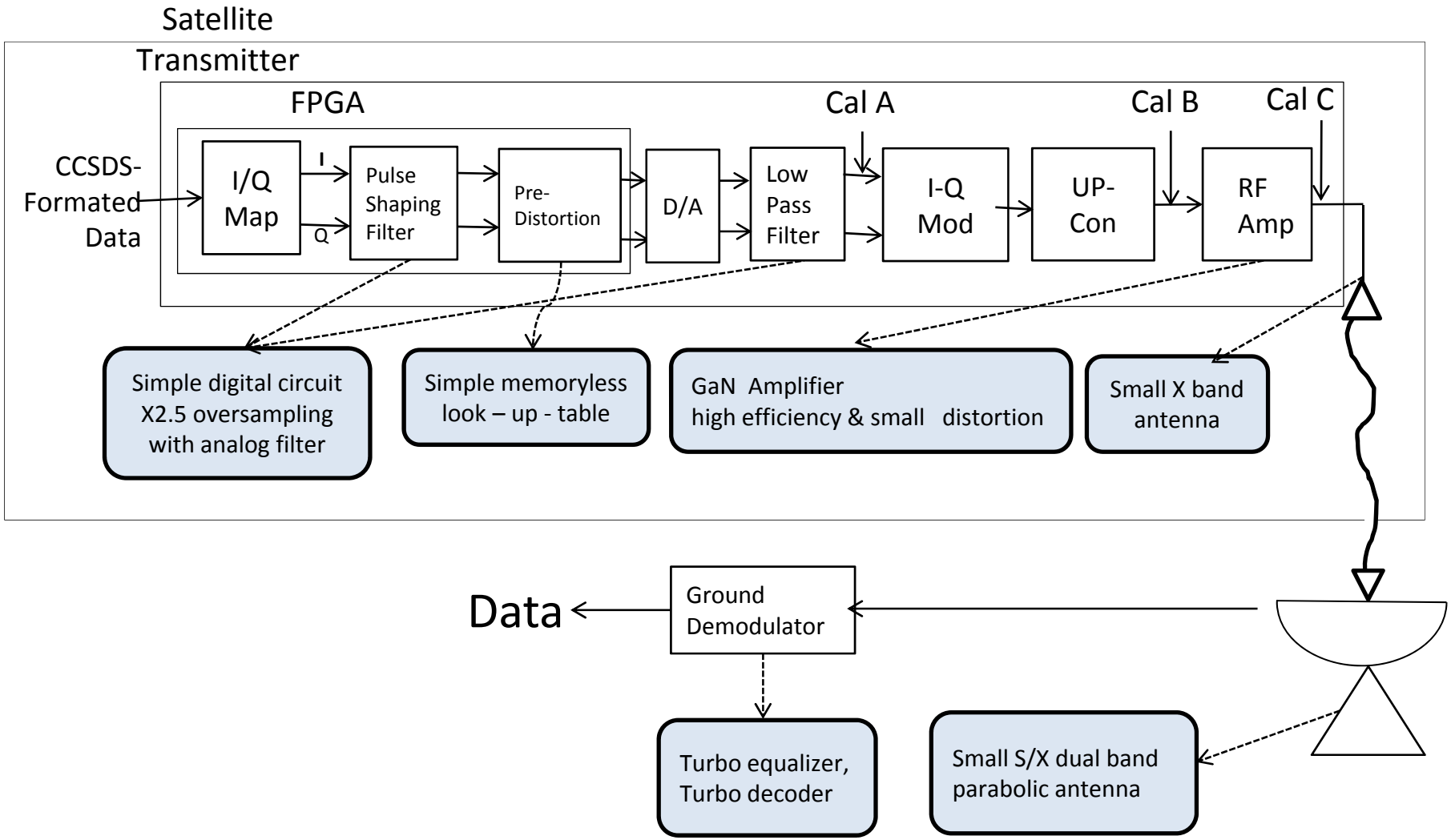
  —Goal

  50kg Sat @600km orbit

  DC power <20W, 320Mbps

  Small Ground Antenna < 4m

System block diagram of high-data-rate downlink.

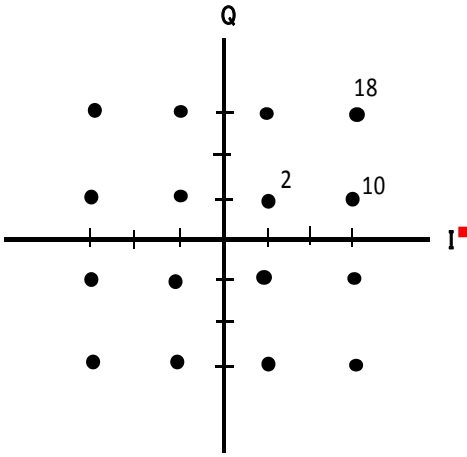


Performance of High - Data - Rate Down Link

Instruments	Mass (g)	Power (W)	Remarks
On-board			
Transmitter	1330	18	16QAM, 348Mbps GaN Power Amp.
Antenna			
MGA	69	0	13.5 dBi
Iso-flux	150	0	5dBi(60°), -2dBi(0°)
Ground Station			
Antenna	3.8m Dia. S/X Cassegrain, 47.5dBi(X), 36dBi(S), Sys. Noise temp. 100K		
Demodulator	100Msps, (348-144Mbps), 16QAM, QPSK SCCC Turbo Equalizer CCSDS 131.2-B-1		

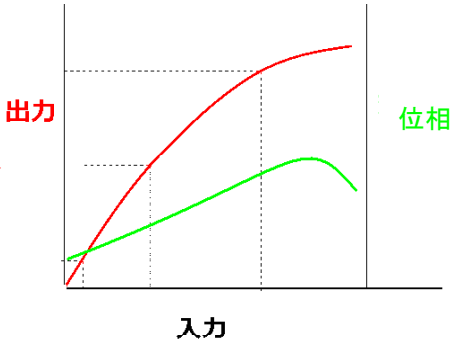
High-Speed 16QAM Down Link with Nonlinear Amplifier

Input IQ Constellation



1 sumbol transmits 4 bits

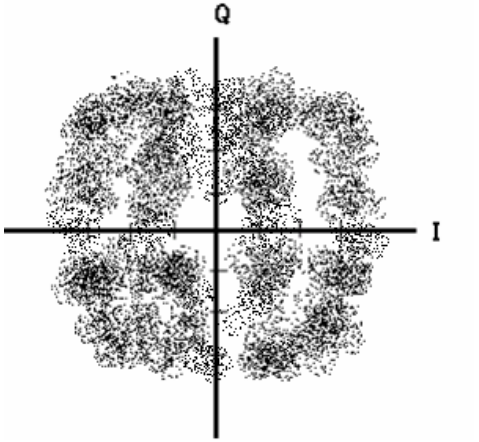
Nonlinear Amplifier



AM & PM Distortion

位相回転

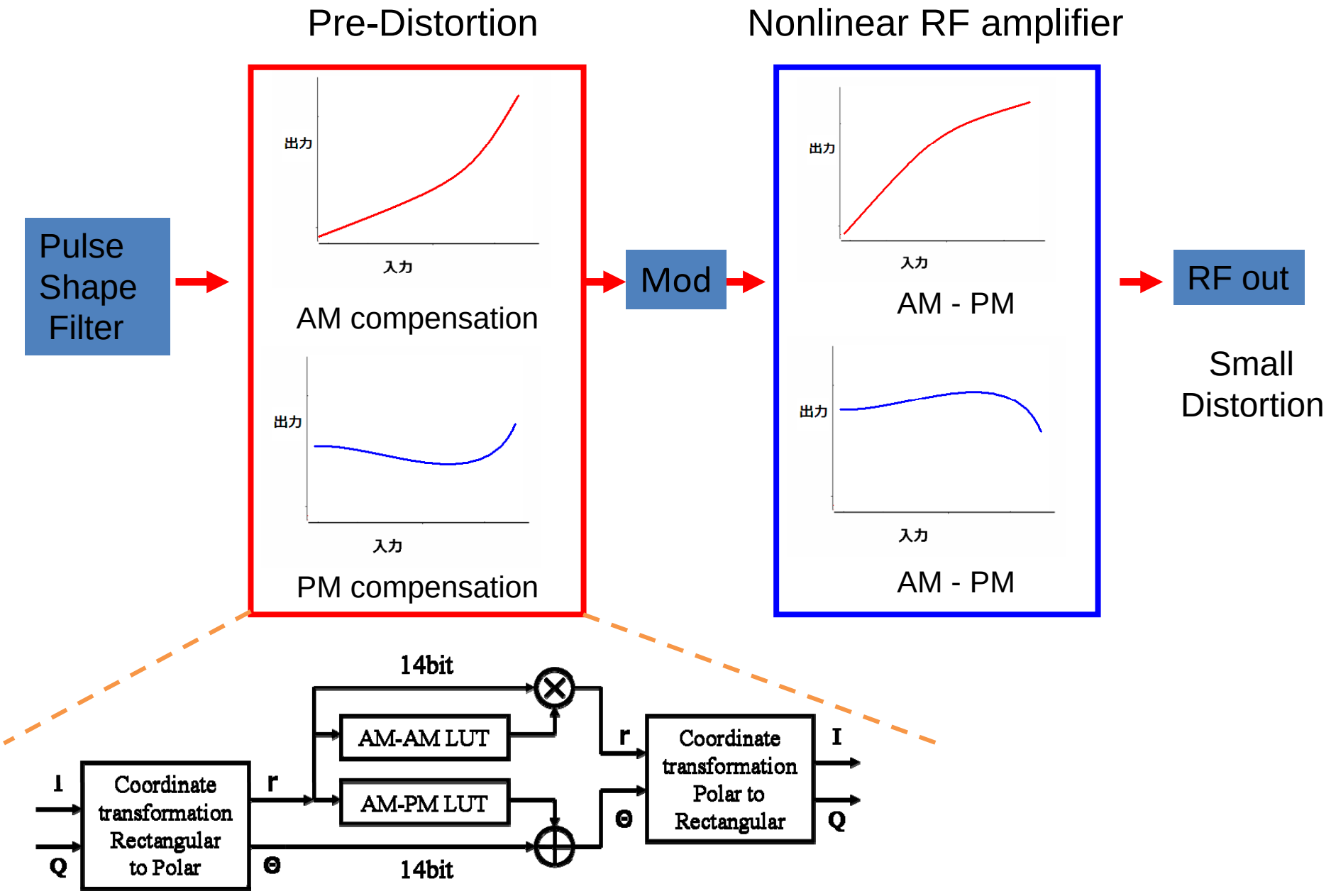
Output I-Q Constellation



Inter Symbol Interference

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

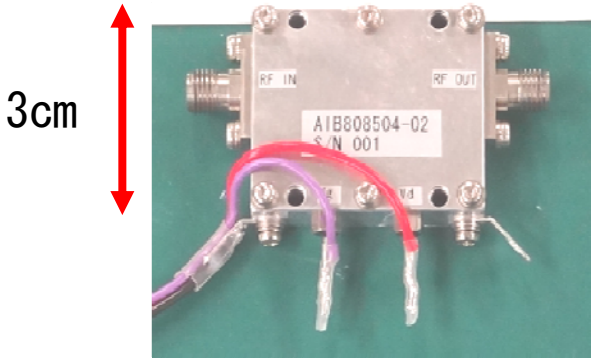
Digital Pre-distortion compensates Nonlinearity



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



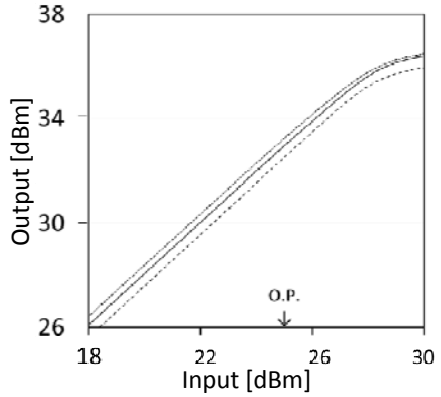
AM/AM

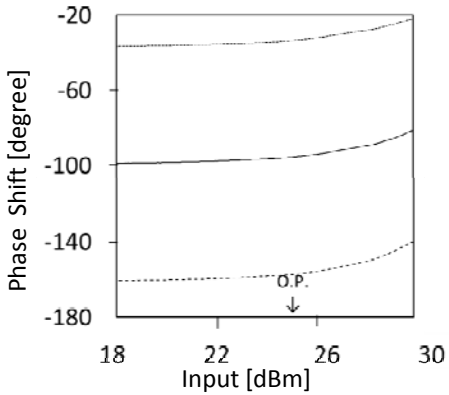
AM/PM

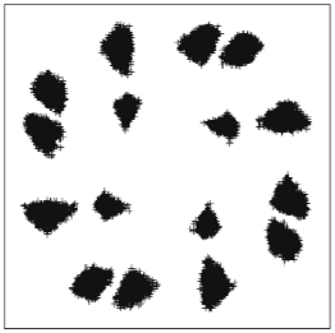
IQ Constellation

Without Pre-distortion

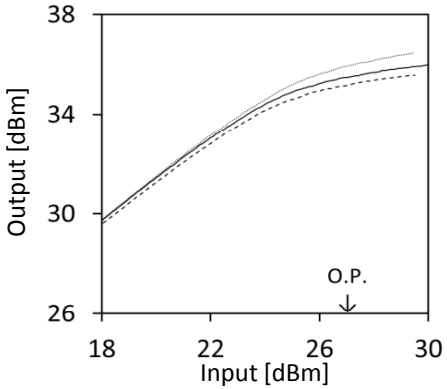
GaAs (AB)

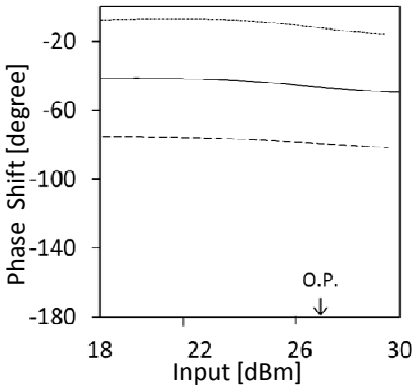


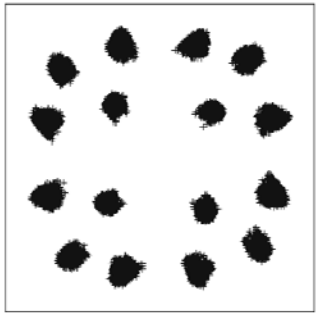




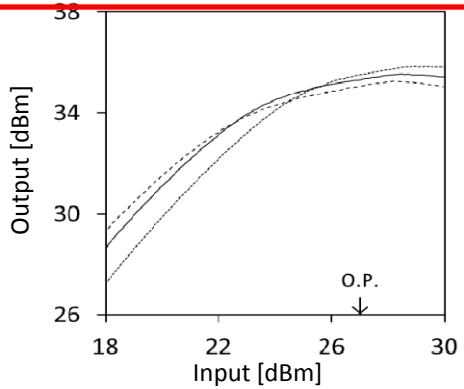
GaN (AB)

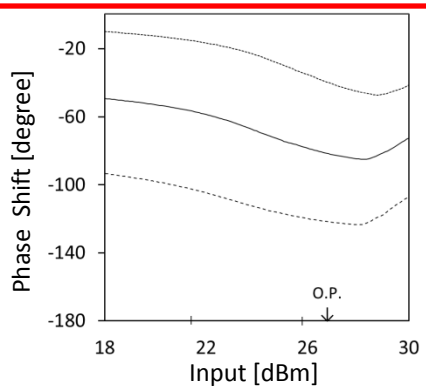


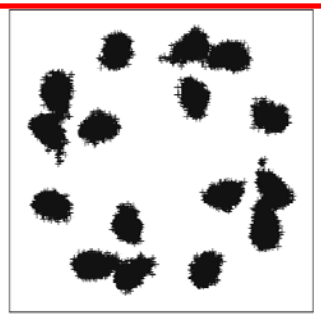




GaN (F)







AM/AM

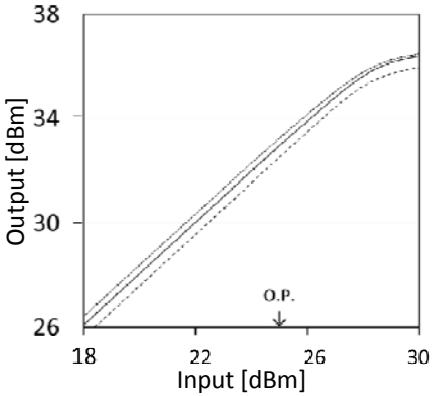
AM/PM

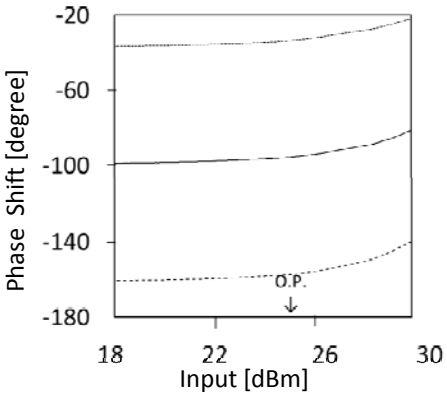
IQ Constellation

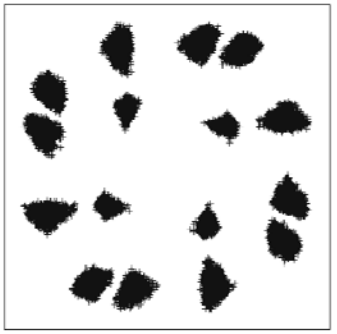
Without Pre-distortion

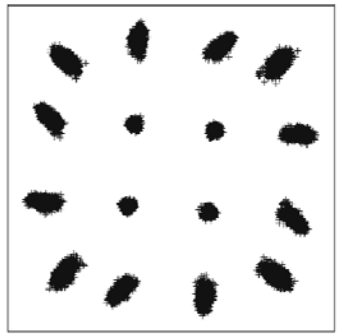
With Pre-distortion

GaAs (A)



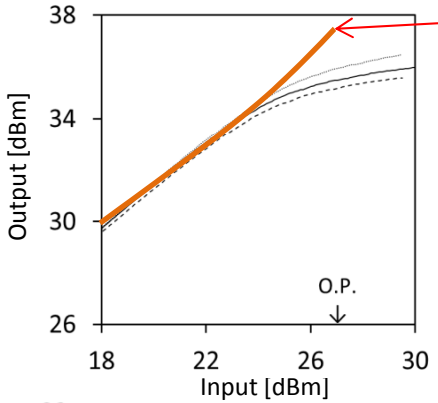


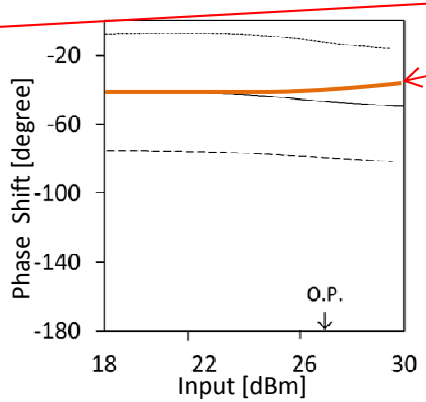


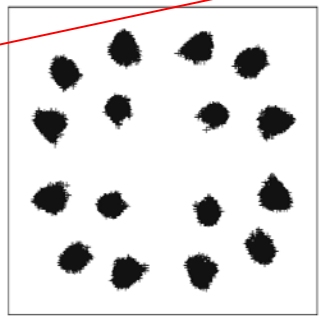


Pre-distortion

GaN (AB)







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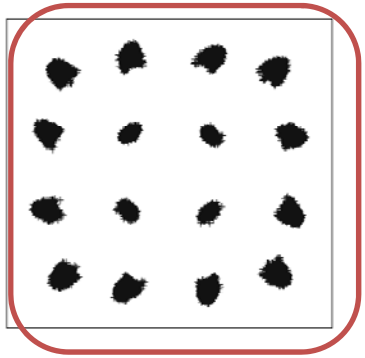
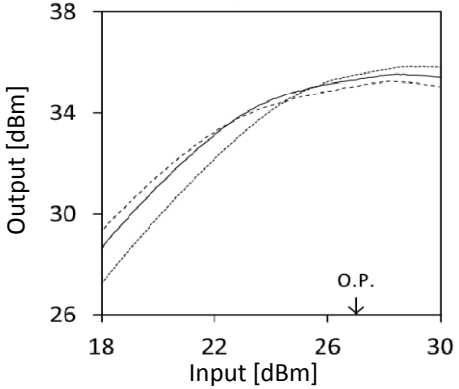
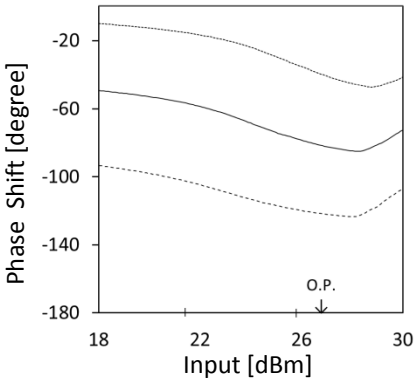
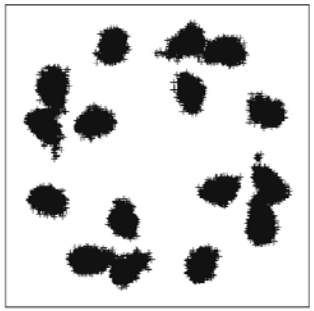
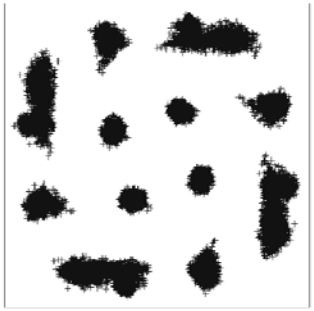


GaN (F)

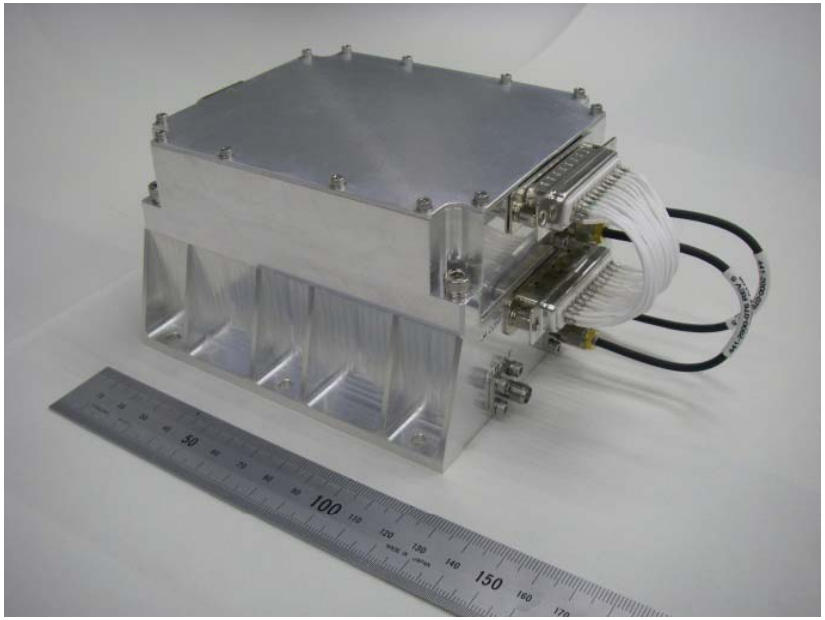








EM of 348 Mbps Transmitter



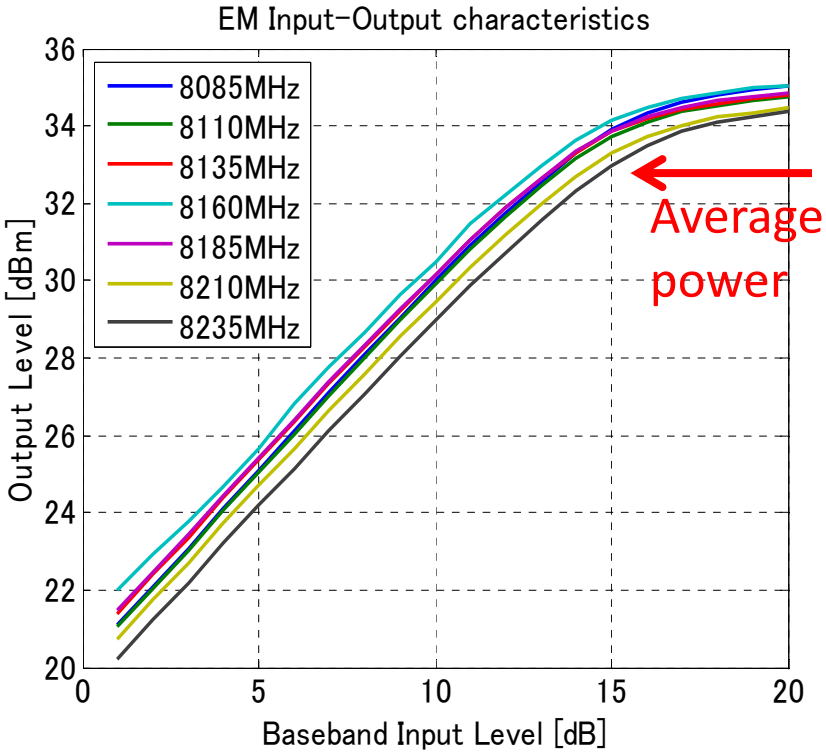
Modulation:16QAM/QPSK
Mass : 1330g
RF Power: 2W
DC Power :20W

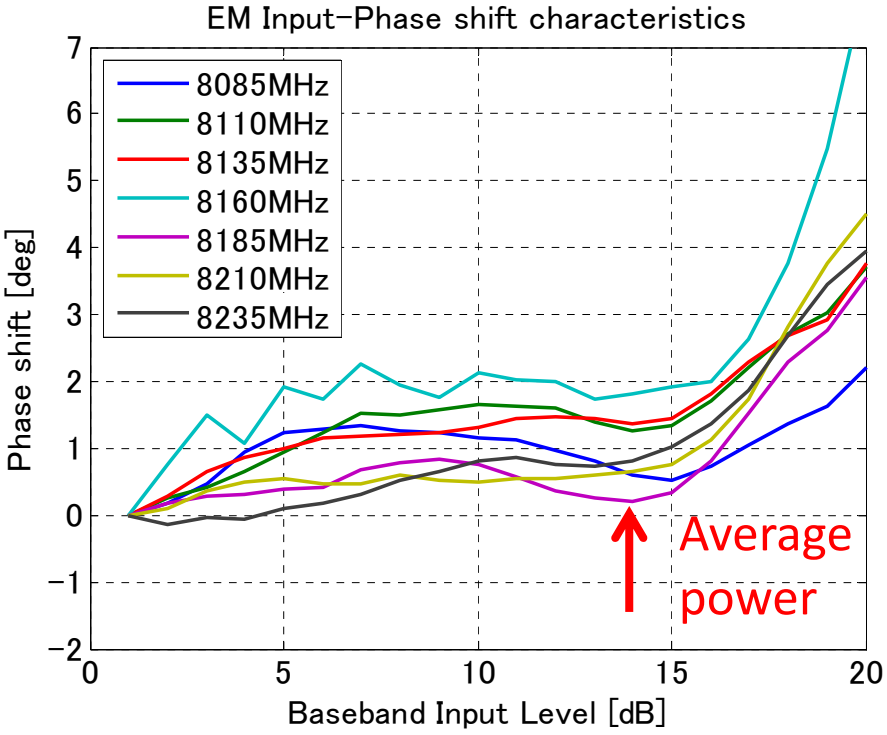
AM-AM, AM-PM Characteristics
X-band Transmitter (EM)

Efficiency(PAE) 47% (PA, GaN-HEMT)

Output Backoff 2dB

Phase Shift 2 deg (average)

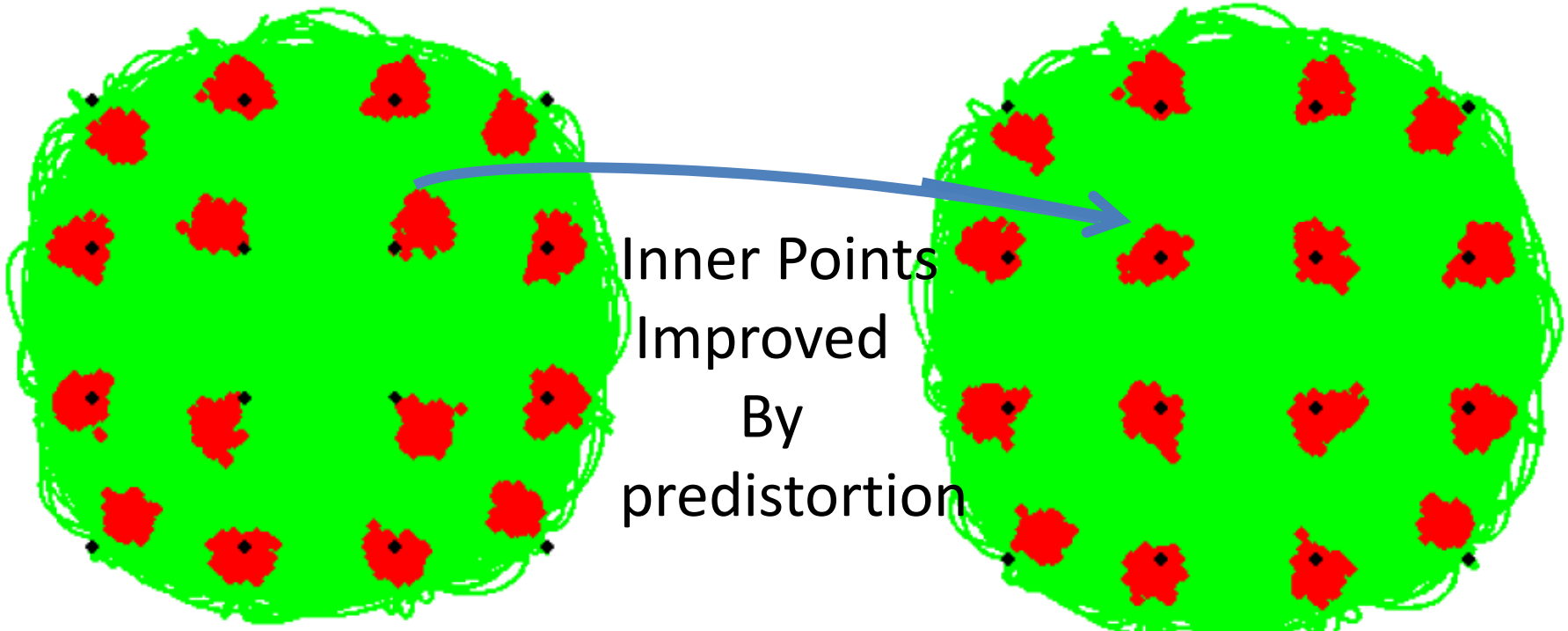




16QAM I/Q Constellation @ 33dBm
(EM_RF block)

Without Predistortion

With Predistortion

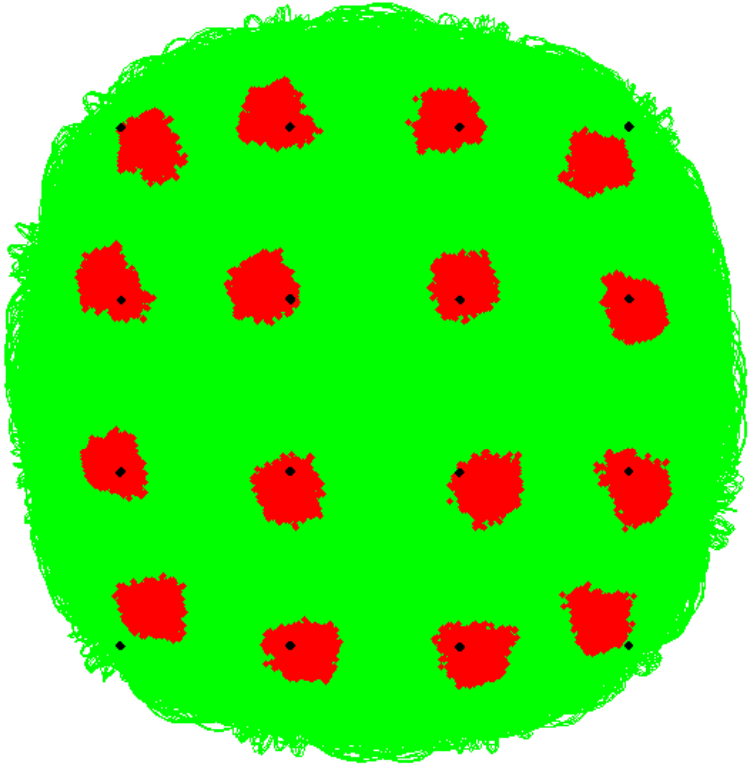


(a)Without pre-distortion

(b)With pre-distortion

16QAM I/Q Constellation @ 33dBm (PM RF+Digital)

Without Predistortion

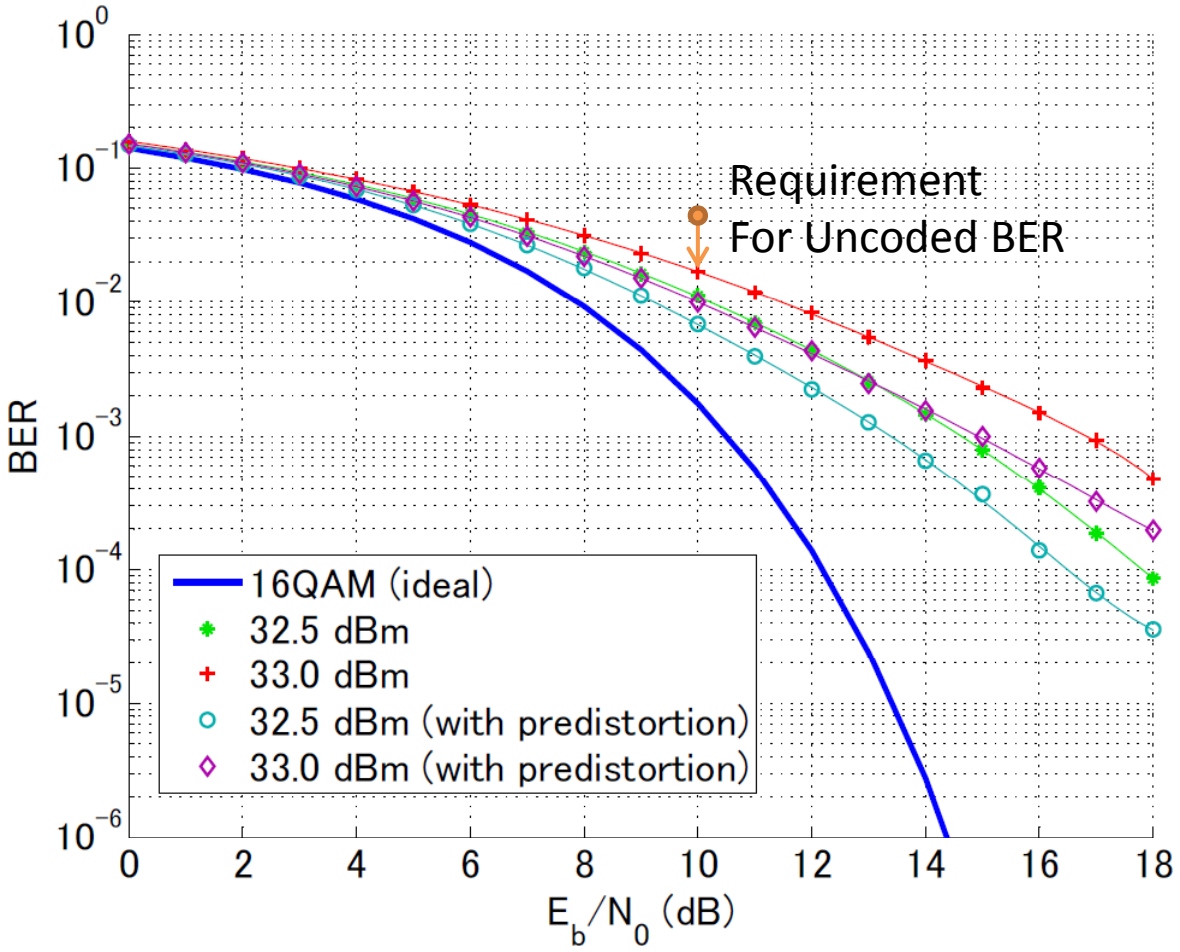


ceived from the prototype model of transmitter without predistortion. RF output power = 33 dBm.

Bit Error Rate v.s. Eb/No

EM RF Block, uncoded 16QAM

When Uncoded BER < 5×10^{-2} at E_b/N_o =10dB,
SCCC + Turbo Equalizer / Deoder achieves BER < 10^{-6}.

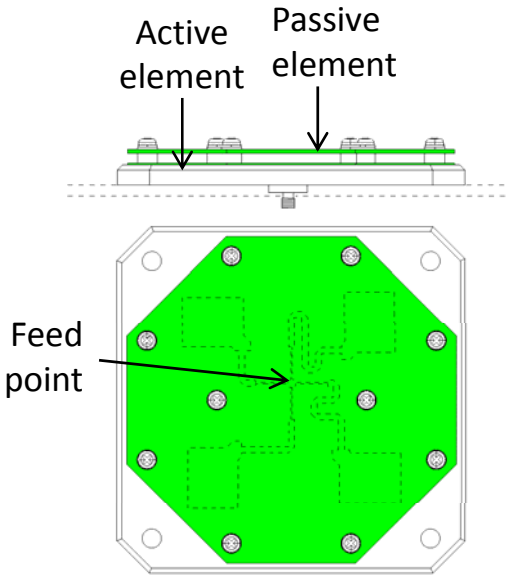


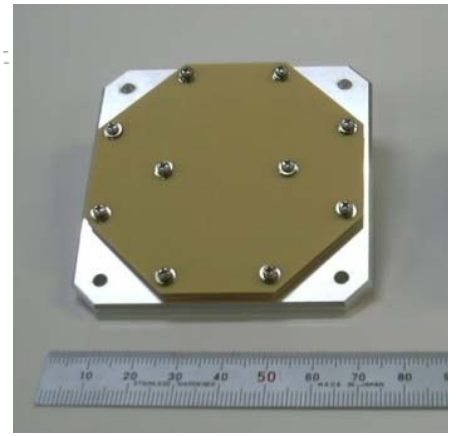
Onboard Small Antenna

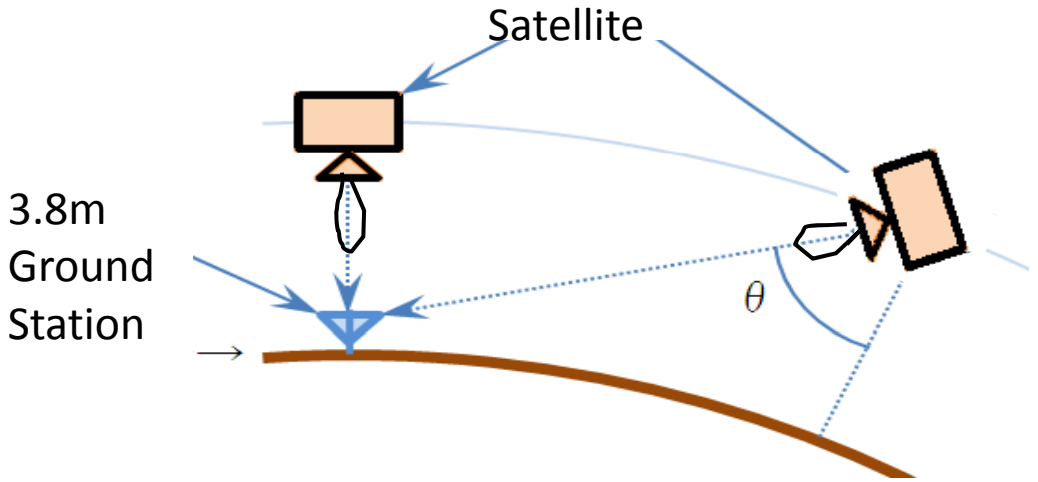
Body-Fixed Medium Gain Antenna

14 dBi, 68g

14 dBi, 68g, 7x7cm







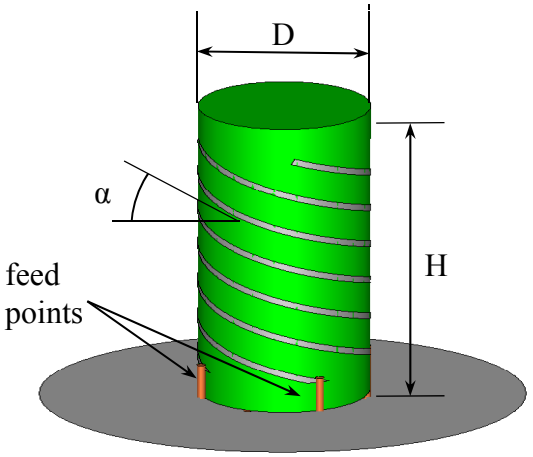
For 320Mbps high bit rate mode,
Satellite points earth station

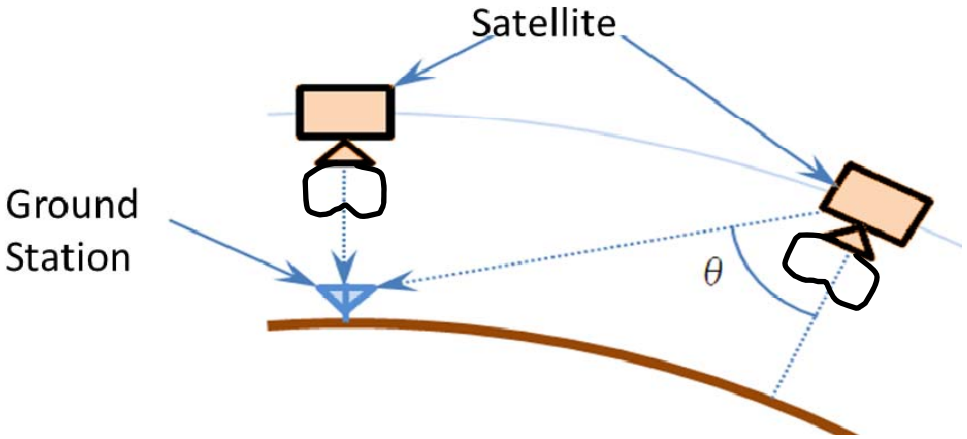
Onboard Small Antenna

Body-Fixed Iso-flux Antenna

5dBi max, 150g

qaudrafilar helix
150g, D=10mm, H=20m





For Earth-Pointing Satellite,
Antenna pattern compensates
range variation

Ground Antenna

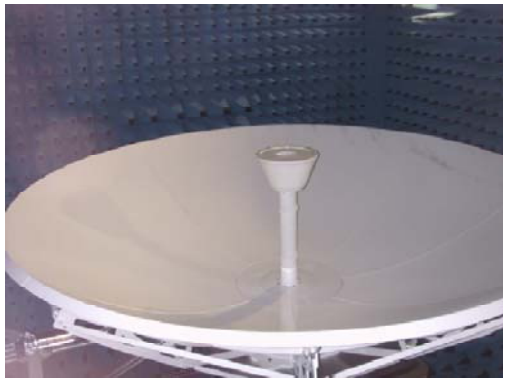
3.8m Ground Antenna for S / X Band

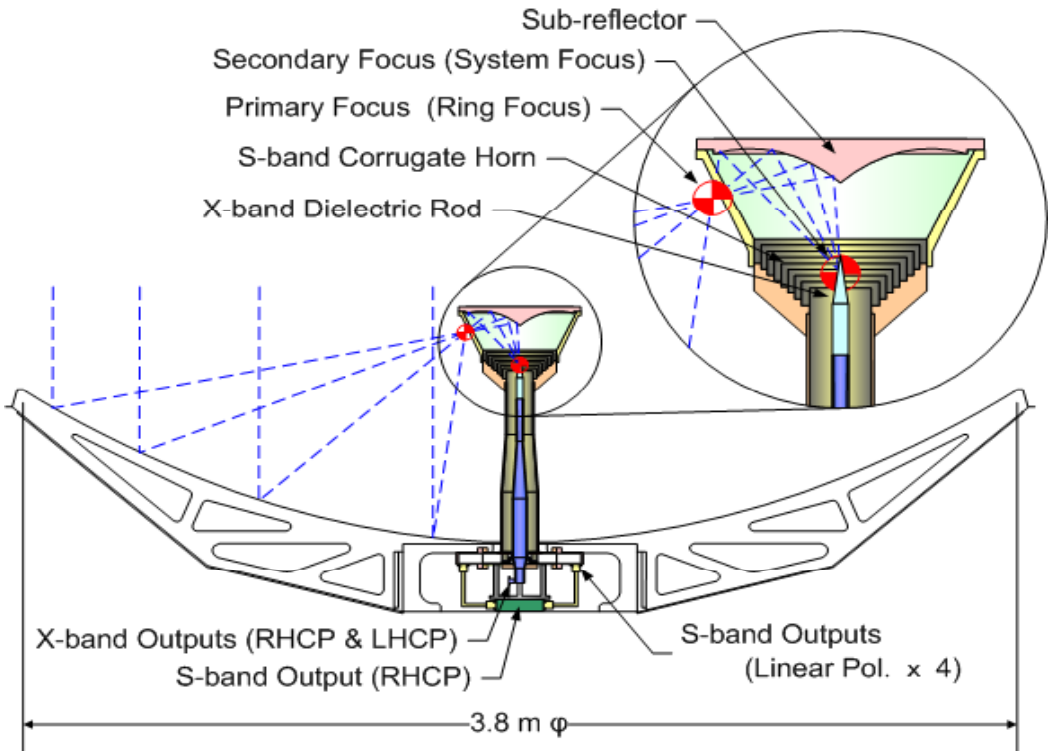
S band : Telemetry & Command

X band : Mission Data Down Link (320Mbps)

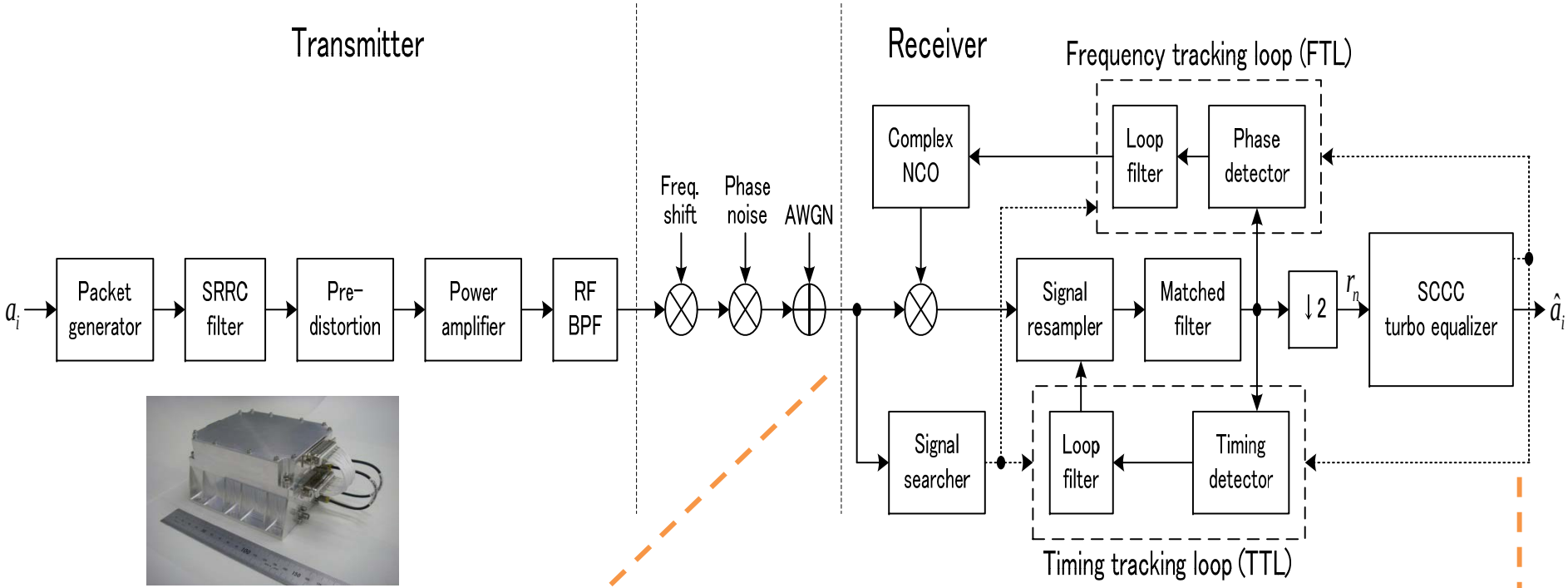
Ring-Focus

Cassegrain



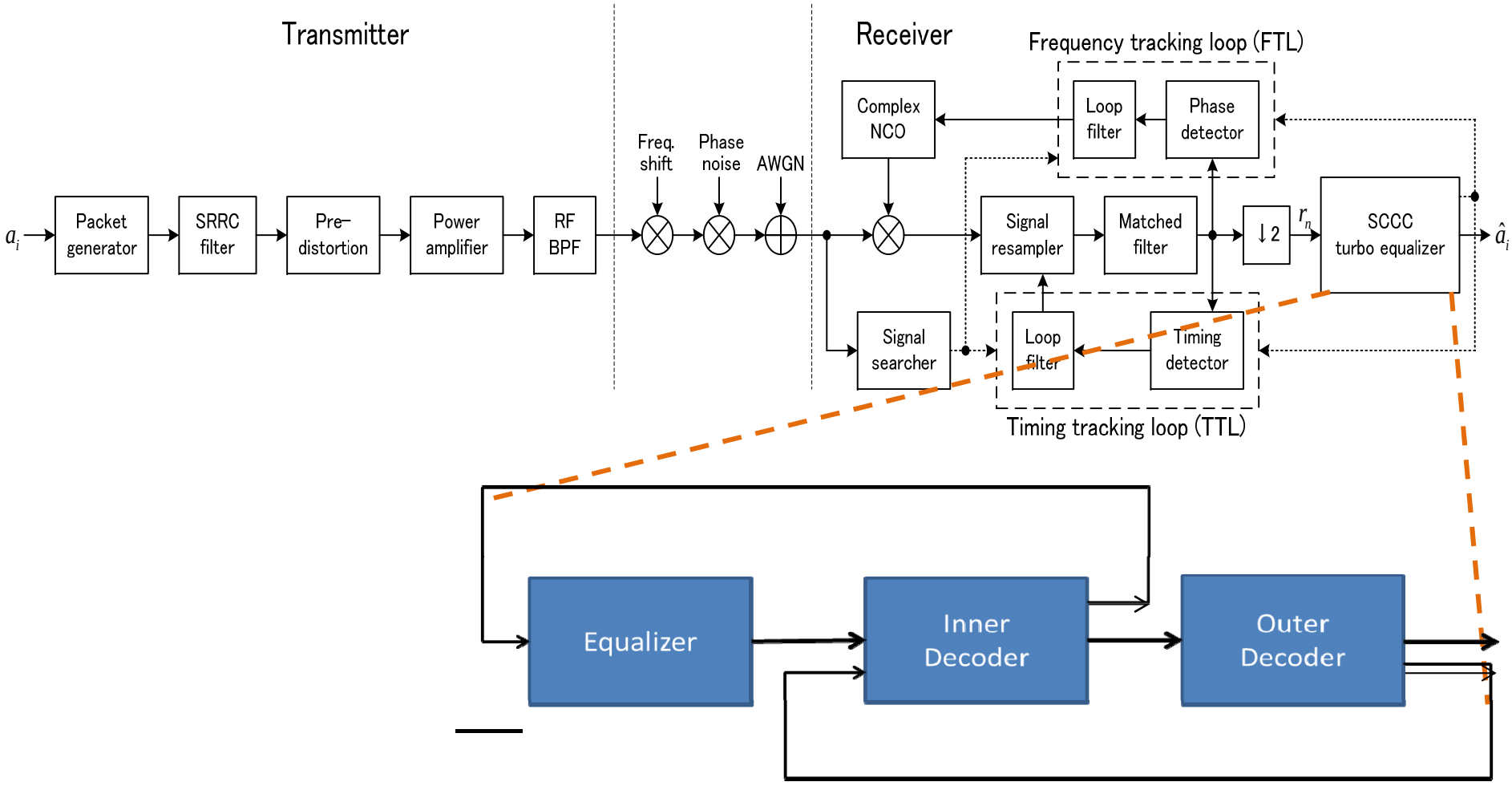


Block diagram of high-data-rate downlink and ground receiver



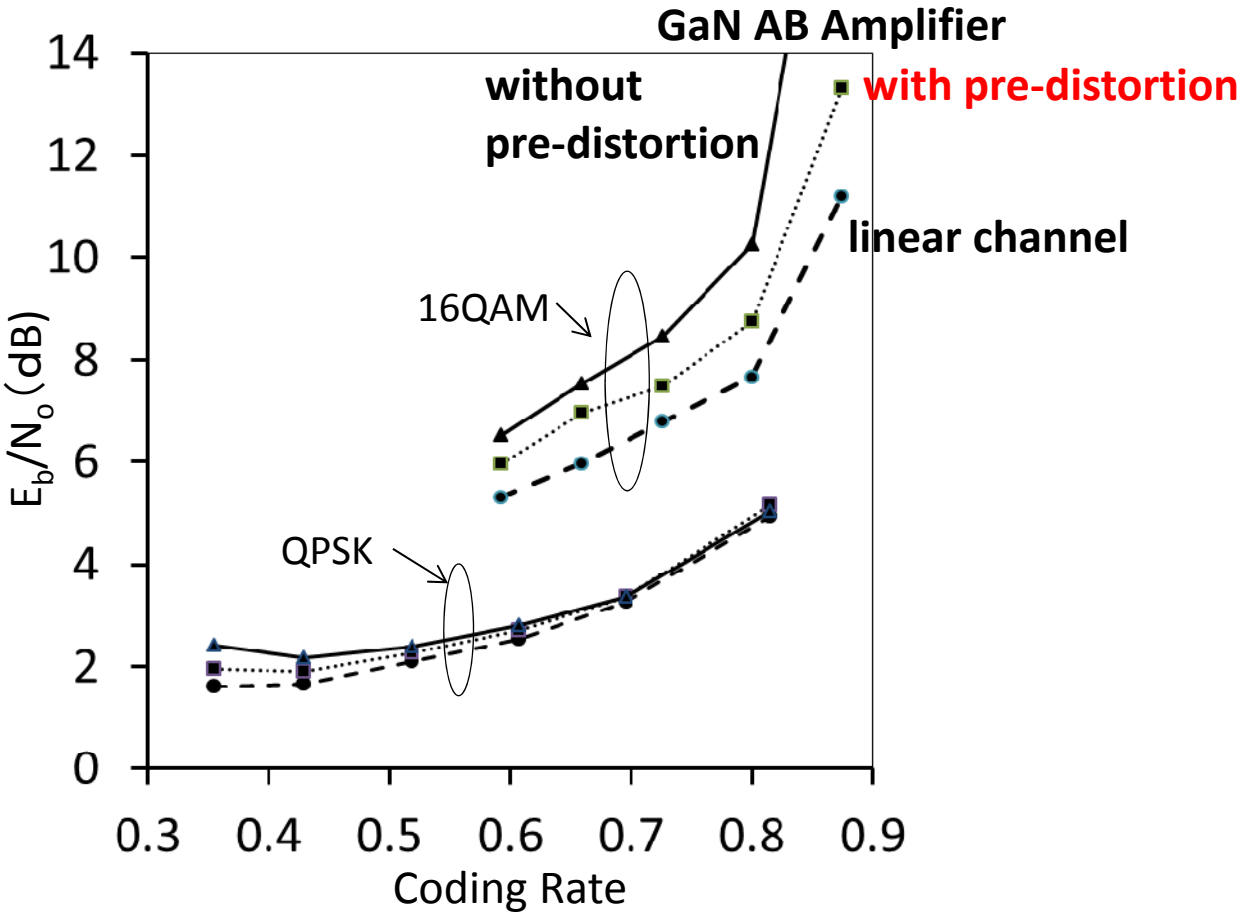
Developing 400Mbps
16QAM ground receiver

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



Simulation

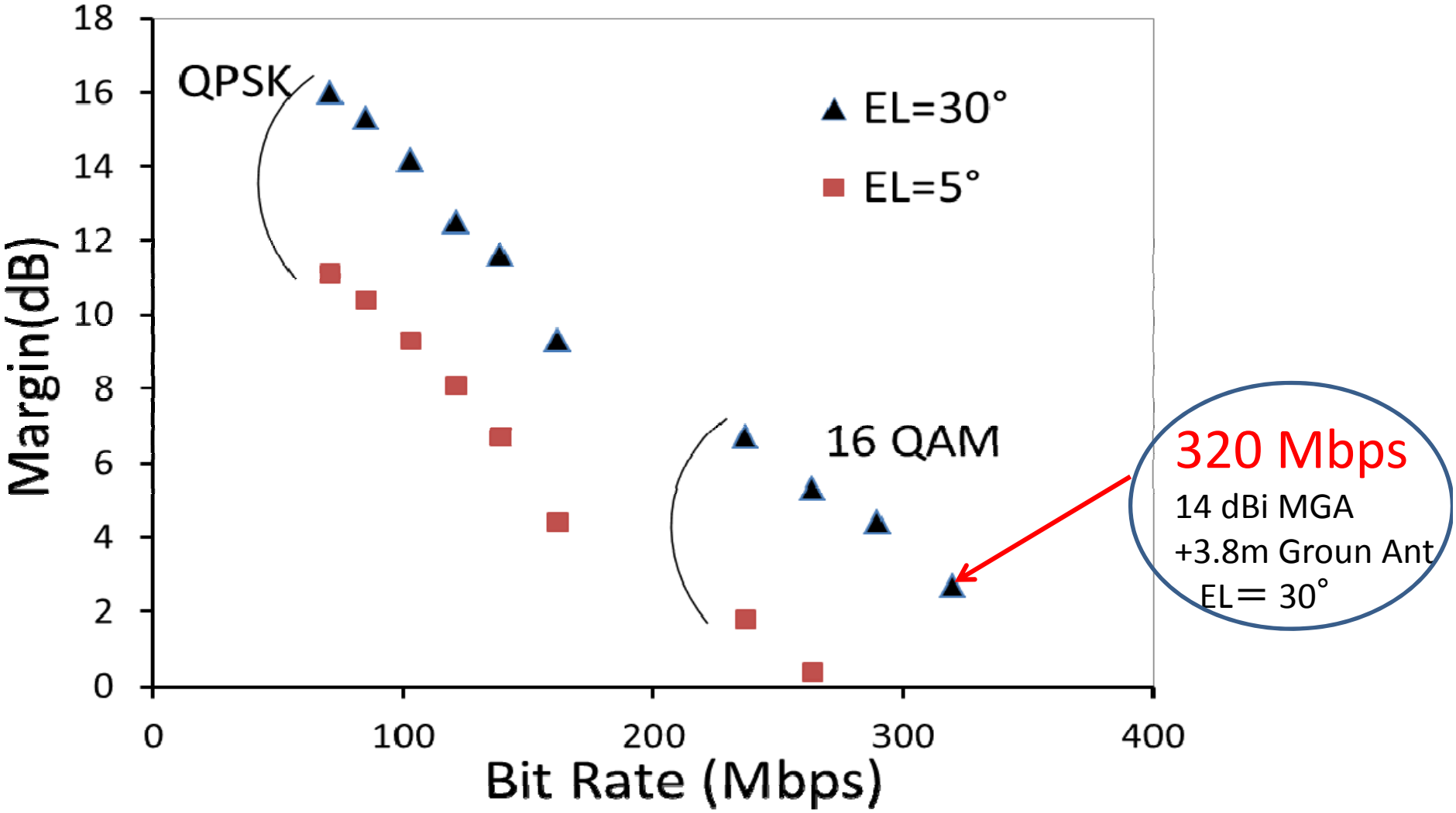
Required Eb/N0 for BER = 10-6



CCSDS 131.0 SCCC

Link margin of high-data-rate down

(2W GaN HEMT of AB class with pre-distortion)



Project Schedule

Onboard Transmitter

- ’13 June T EM test
- ‘13 June-Sep. FM manufacturing
- ‘13 Oct. PM test
- ’13 Nov. FM test

Ground Antenna

- ’13 March Installation

Ground Receiver

- ’13 Nov.-Dec. Front-End install
- ‘14 Feb. Complete (collimation test)

Hodoyoshi - #4 (60kg) Launch

- ’14 March by Dnepr
- ’14 Demonstration 320Mbps 16QAM test on orbit

Now !

Goal !

Conclusions

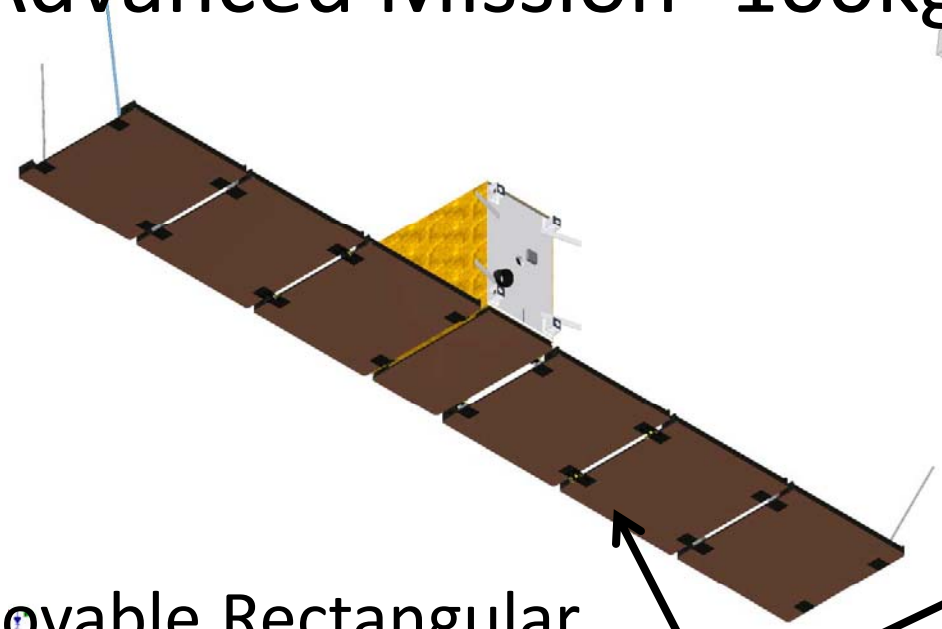
1. Developing 320Mbps 16QAM down link for 50kg satellite.
2. Power-efficient transmitter

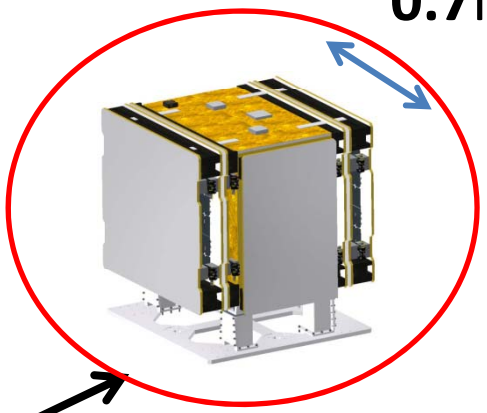
   (GaN HEMT amp with predistortion)

   small antenna (MGA, isoflux)
3. Small ground antenna,

   powerful receiver (turbo equalizer & decoding)
4. On-board demonstration in 2014 with 50kg sat.

Advanced Mission -100kg SAR Satellite-



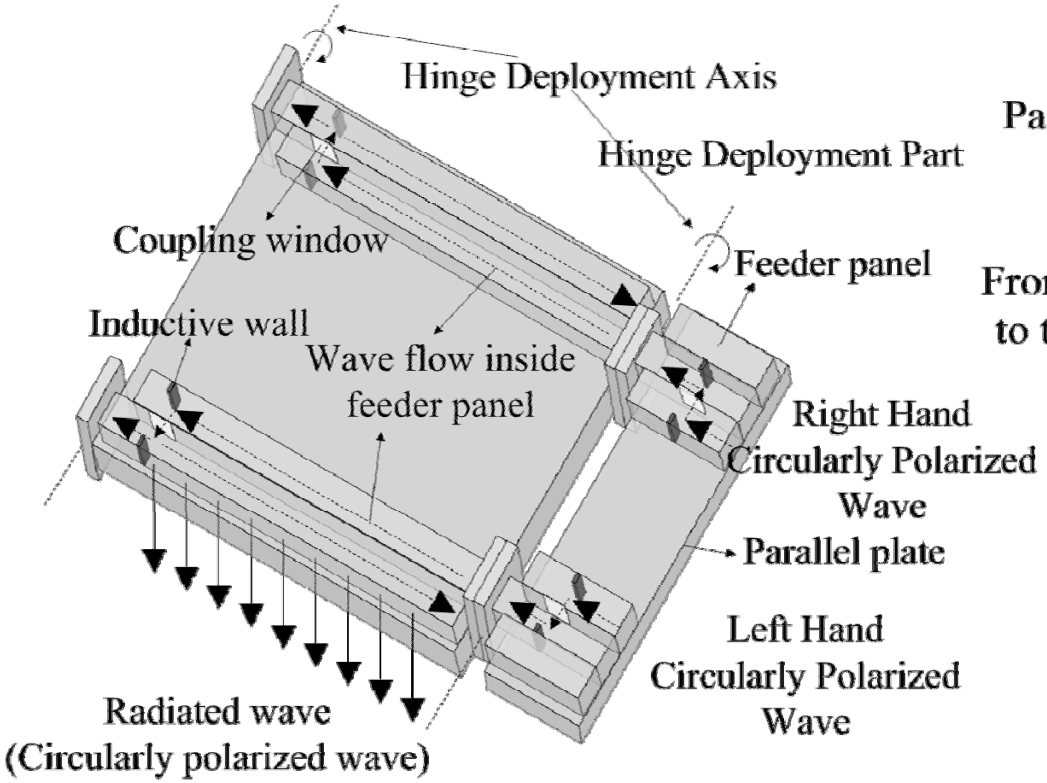


- Deployable,Rectangular, Slot Array Antenna with Waveguide Feeder

- Compact stow volume 0.7x0.7x0.7m
- Front panel: SAR antenna
- Rear panel: Flexible Solar Cell

Deployable Slot Array Antenna

(a) Backside and Waveguide Feeder



(b) Slot Array Antenna Panel
(Feeder is removed)