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Technical Challenges for Small SAR Satellites with High Performance

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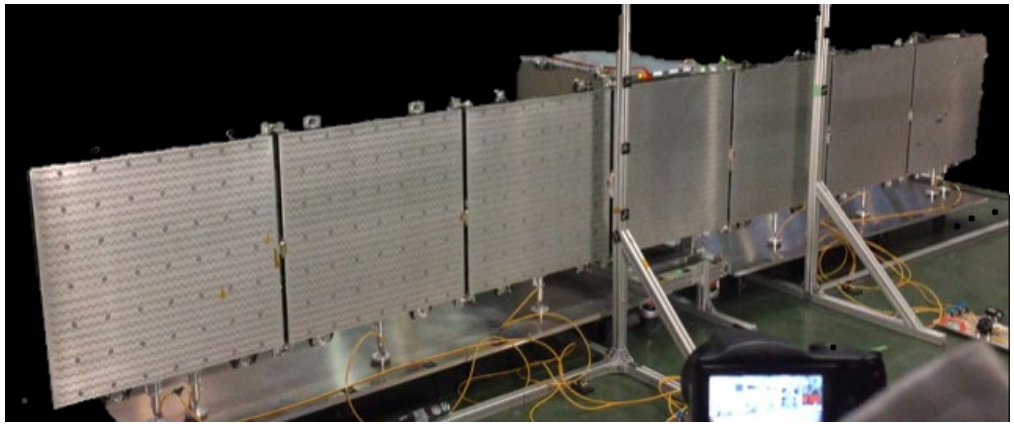
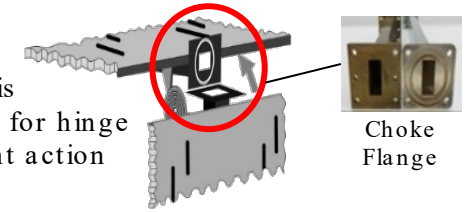
Contents

1. JAXA /Tokyo Tech Inst have developed Small SAR system with unique passive array antenna.
   The first in-orbit demonstration was by start- up company
   Synspective in 2021. Feb.
2. This paper describes next **Technical Challenges for Small SAR Satellites with High Performance.**
3. Mission requirement of SAR constellation
   & Technology challenges
   Resolution, Swath,
   SAR antenna type, Bandwidth, High RF power
4. Topics
   CFRP antenna, Bandwidth of slot array antenna,
   RF breakdown problem of high power GaN SSPA

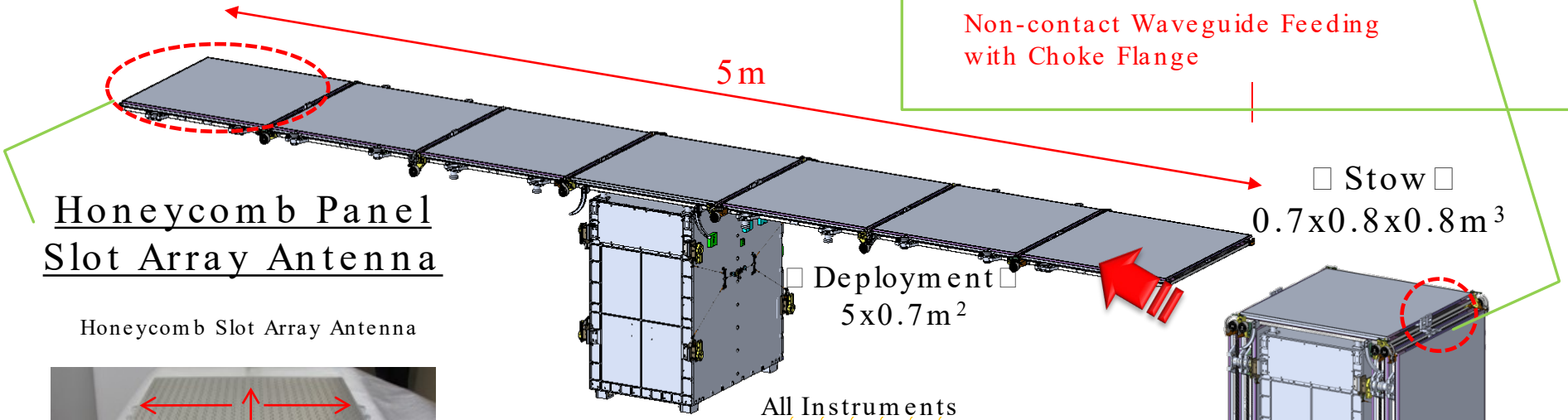
Small SAR Satellite, Micro-X-SAR
Compact Honeycomb Panel Slot Array Antenna & Non-contact Waveguide Feeding



Compact Antenna Feeding

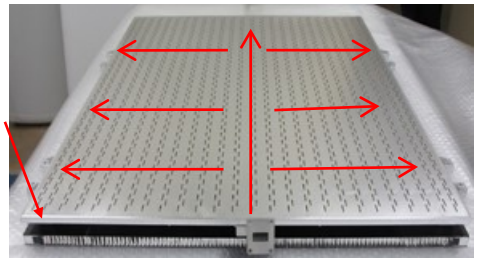


Non-contact Waveguide Feeding with Choke Flange



Honeycomb Panel Slot Array Antenna

Honeycomb Slot Array Antenna



Waveguide Tournament Feeder

On-orbit Demonstrated in 2021 Feb.

15cm

Fundamental Relations

1.Range Resolution ∝ Frequency Band Width

Ground resolution	Band width
1m	300MHz
0.5m	600MHz
0.25m	1200MHz

2. Radar Equation: $$\sigma_{NE}\circ\delta_r = (8\pi R^3 k T_o v_{st})(NFL_s)\frac{\lambda}{P_{TX-ave}A^2\eta^2}$$

Range Resolution x NESZ ∝ (Average Power)$^{-1}$ (Antenna Area)$^{-2}$

3. Antenna Size & Beam Width

RF Beam Width ∝1/ (Antenna Size)

600MHz, 1200MHz >3kW

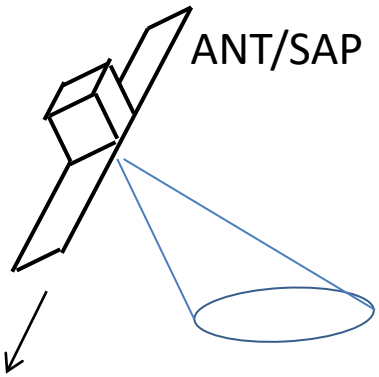
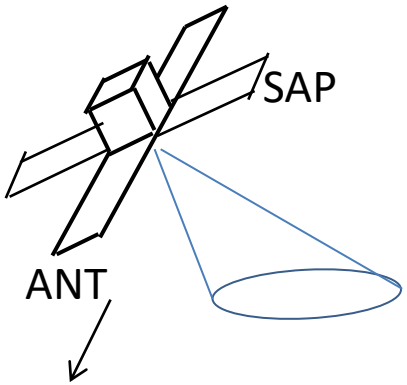
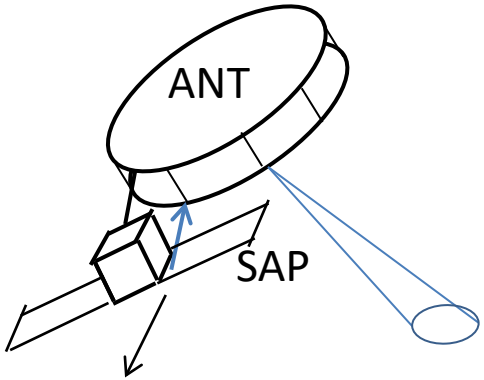
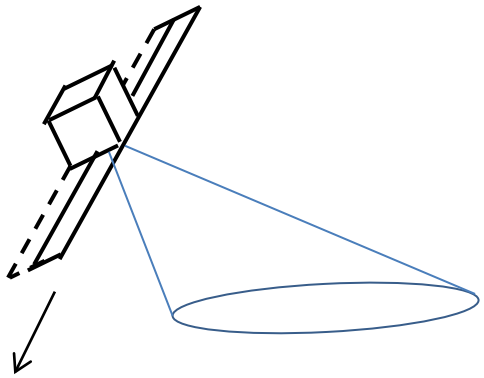
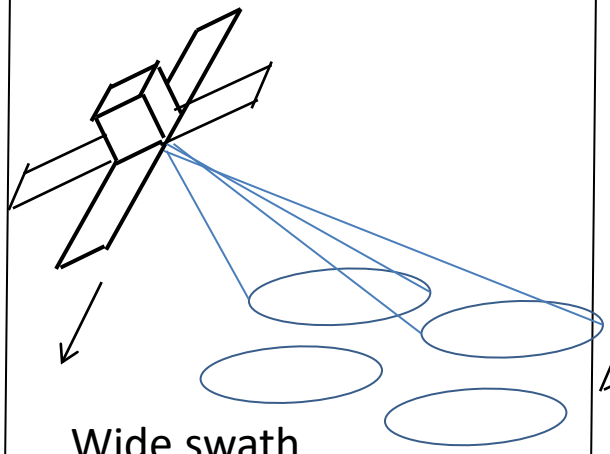
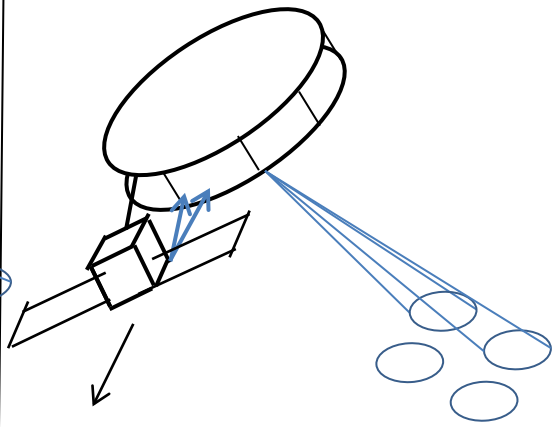
High Resolution SAR ⇒ Wide Band, High Power

Wide Swath SAR ⇒ Beam Scan, or Narrow Antenna, High Power

Requirement from Recent SAR Constellation Missions

Spec. \ Application	Constellation	High Resolution	Wide Swath
Low Cost	Required		
Mass Productivity	Required		
High TX Power		Required	Required
Wide Frequency Band		Required	
Wide EL Beam /Scan EL Beam			Required
High Speed Data Processing		Required	
Large Data Volume			Required

Summary of SAR Antenna and SAR Application

	Passive Phased Array	Active Phased Array	Parabola
Merit/ Demerit	Low cost (simple honeycomb antenna with solar cell) Medium swath/resolution	Wide swath High cost	High resolution Narrow swath
High Resolution Mode			
Wide Swath Mode	One subpanel excited 	Scan SAR mode 	Primary feeder scan 

Toward Next generation of Micro-X-SAR

	Present		Next Generation	
SAR Mode	Standard Stripmap Mode	Standard Spotlight Mode	Wide Swath Stripmap Mode	High Resolution Spotlight Mode
Ground Resolution	3.2m	0.8m	6m	0.4m
Swath	20km Swath	20kmx20km	40km Swath	20kmx20km
TX Power	1kW	1kW	3kW	3kW
On-Duty	25%	25%	15%	25%
Excited Ant. Aeria	5m x 0.7m	5m x 0.7m	5m x 0.35m	5m x 0.7m
Bandwidth	75MHz	300MHz	32MHz	600MHz

Technical Challenges

1. CFRP Antenna
   Shape Stability, Mass Productivity, Mass Reduction

2. Wide Band, Wide Swath Passive Slot Array Antenna
   600MHz, 1200MHz in X band
   40km swath

3. High Power GaN SSPA
   > 3kW

CFRP Slot Array Antenna

Merits of CFRP Antenna:

shape stability, mass productivity, mass reduction

Ex.Terra-SAR X

1 D CFRP Sub-Array ⟹ Micro-X-SAR

2D CFRP Array

Cost Reduction

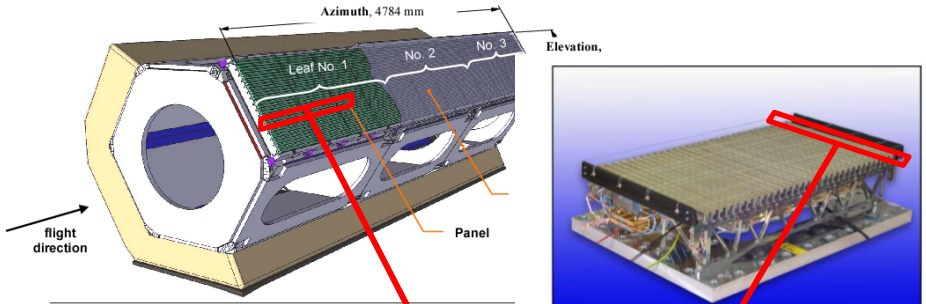


Fig. 1: TerraSAR-X S/C with SAR antenna

Fig. 5. TerraSAR-X antenna panel

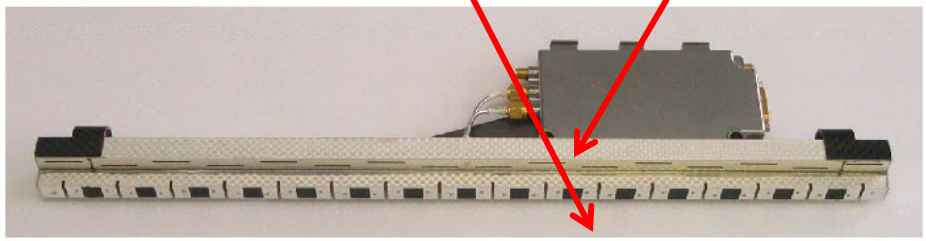
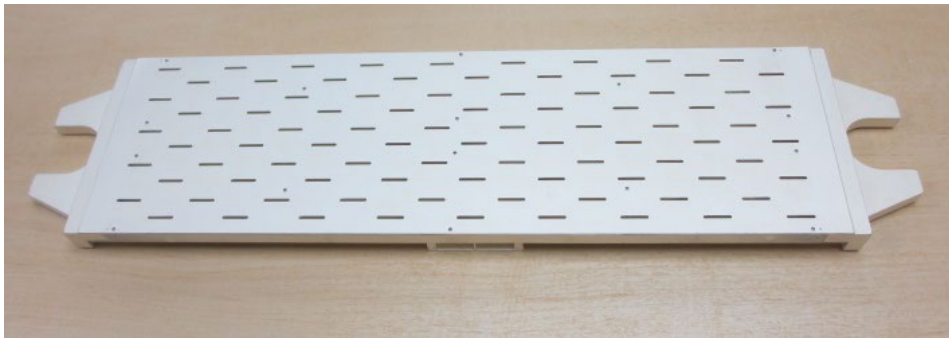


Fig. 2: Dual polarized Sub-array with TR-module

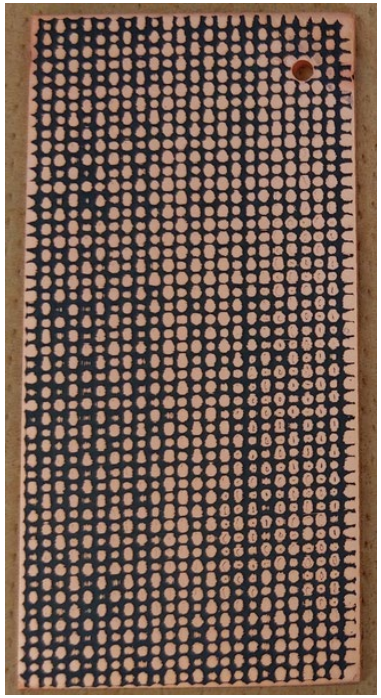
Small scale model, 400mmx140mm
2D CFRP slot array antenna
with Ag plating



Conductive Plating on CFRP

Direct Electro Plating
on cloth type CFRP
Cu deposit
only on Carbon Fiber

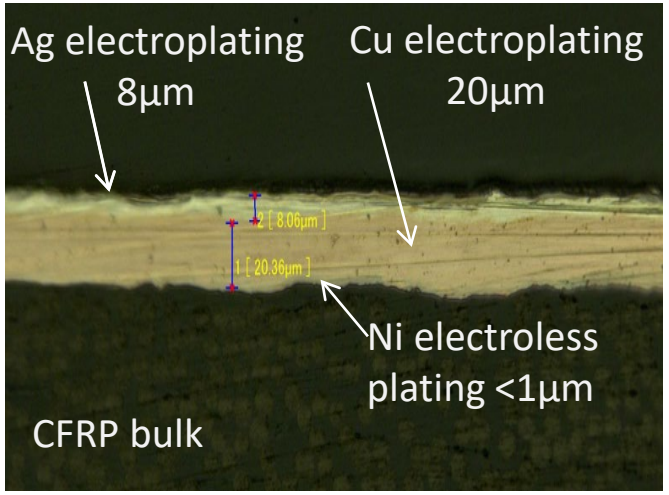
Three Stage Plating on CFRP
Ni electroless plating
⇒ Cu Electroplating
⇒ Ag Electroplating



Nomura Plating Inc.

Nomura Plating Inc.

Cross section



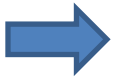
Suzuki Hitech Inc.

Wide Band Slot Array Antenna

Series Feeding

Bandwidth BW is limited by “long-line effect” .

14 x14 Array x 4
BW～400MHz in X band

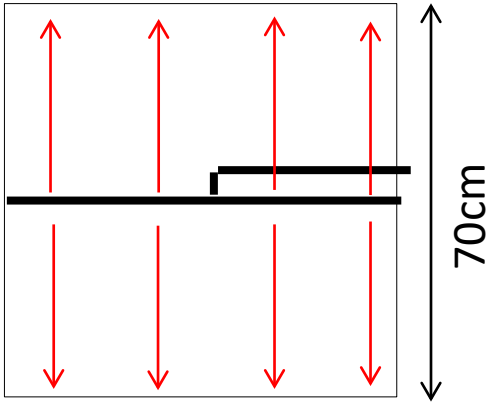


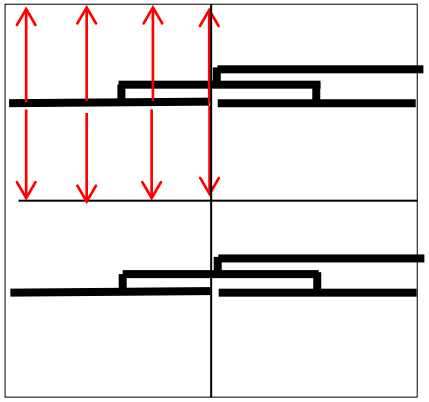
7x7 Array x 4 x 4subpanel
BW～600MHz in X band

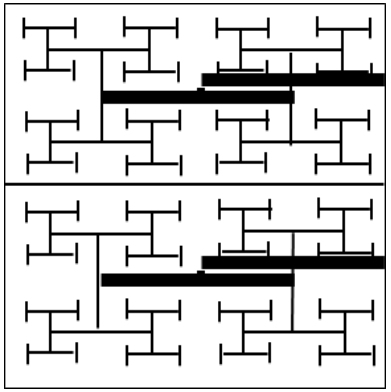
Corporate Feeding

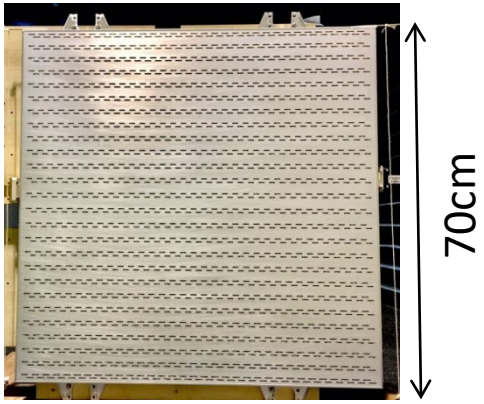
with additional one layer

BW >1200MHz in X band

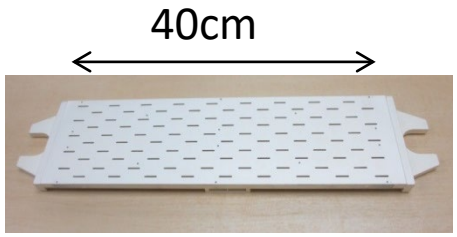




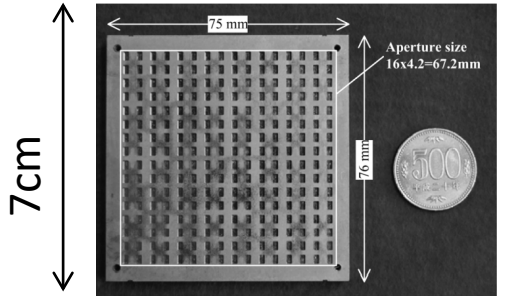




Honeycomb 2D array



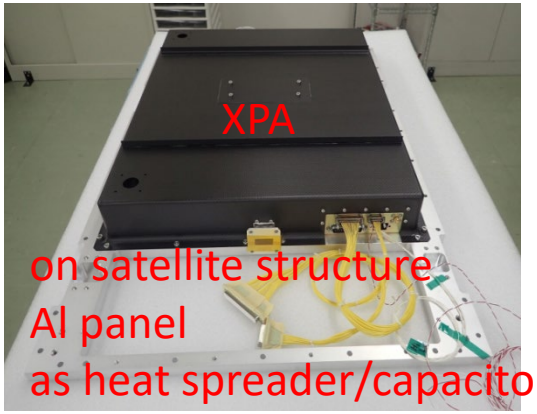
CFRP 2D array



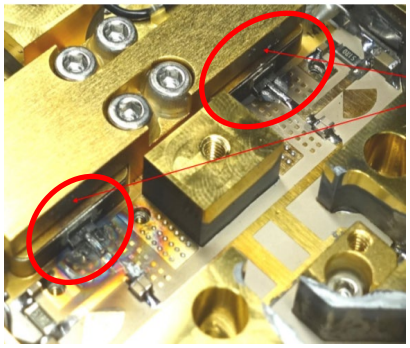
Example of 60GHz,
16x16 Slot Antenna
Tokyo Inst. Technology

High Power X band Amplifier

1 kW, GaN, XPA
demonstrated in orbit



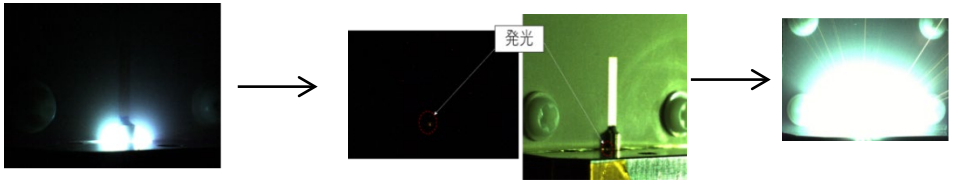
>3kW, GaN, XPA
RF Vacuum Discharge Problem
in Microstripline Junction



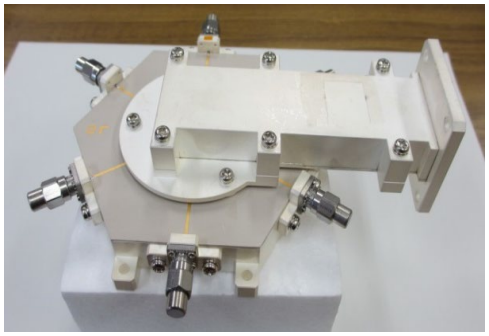
Non-self-sustaining Discharge 412W

Self-sustaining Discharge 551W

Disruptive Discharge 572W



6- power combiner



- Discharge mechanism
  Multipactor/ Gas /Creeping Discharge
- Measure against discharge
  material/surface coating
  with low secondary electron emission

Conclusions

1. Passive 2D Slot Array Antenna is a unique, low cost SAR antenna. Multi mode of moderately high resolution/ wide swath for SAR constellation.
2. Technical Challenges are
   - CFRP Antenna
   - Wide band 2D Slot Array
   - High Power XPA, RF vacuum discharge