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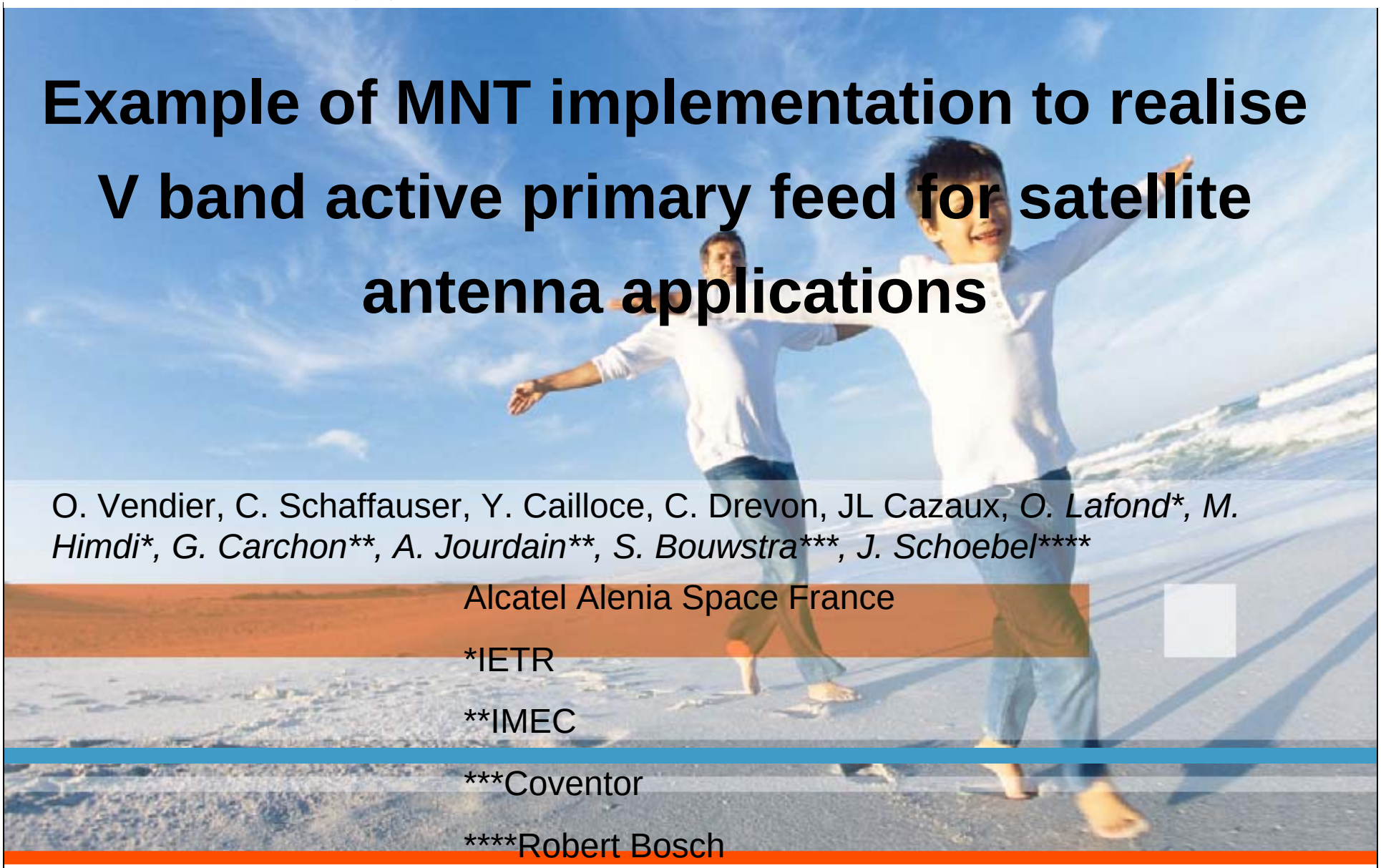
Example of MNT implementation to realise V band active primary feed for satellite antenna applications



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Alcatel Alenia Space France

*IETR

**IMEC

***Coventor

****Robert Bosch

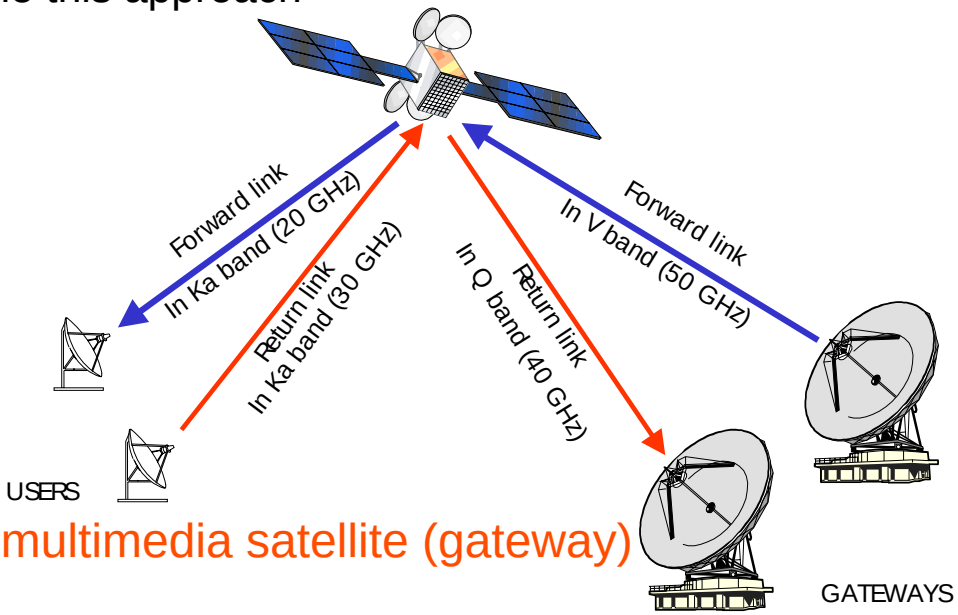
OUTLINE

- Objectives
- Reminder of the specifications and building blocks definitions
- Module definition, design and manufacturing
- MEMS based SPDT technology
- Overall module test results

Objective: V band application ?

Technology driven

- Think of new technological approach to realise integrated active feed antenna
  - Minimizing size
  - Minimizing interconnects budget between the antenna and LNA front-end
  - Use of micro-nano technologies to enable this approach

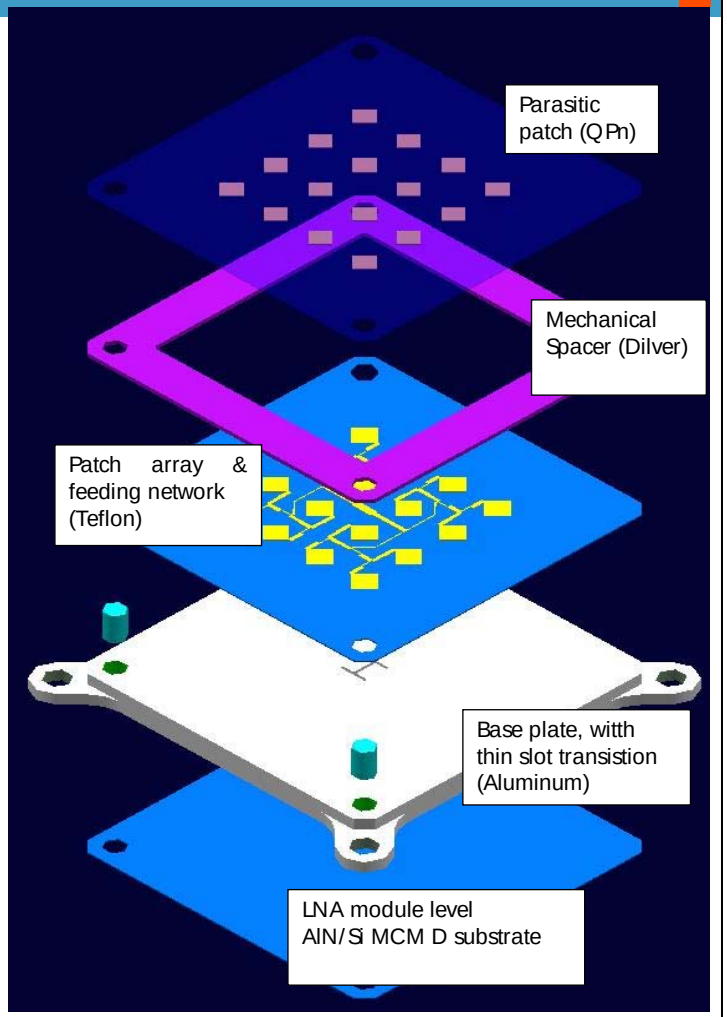


Application driven

- Data truncking for next generation of multimedia satellite (gateway)
- But also
  - Concept to be used in scientific mission for Micro/Nano satellites for example : intersatellite links

Radiating part

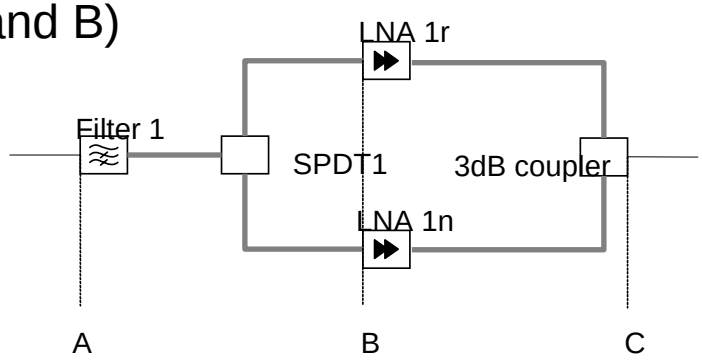
- Preliminary antenna specification and concept :
  - Total efficiency = losses efficiency*surface efficiency = 50%
  - Level of radiated patterns at θ (-12 dB) <24 °
  - Bandwidth : 47.2 - 50.2 GHz
- Assembly and materials
  - 3D stacking approach primary and secondary patch arrays
  - Micromachined thick slot transition (alumina, 2 mm)
  - Effect of radiations have been assessed for use in GEO
  - Use of laser cut, epoxy films, alignment done using pick&place production equipments



Microwave electronic part

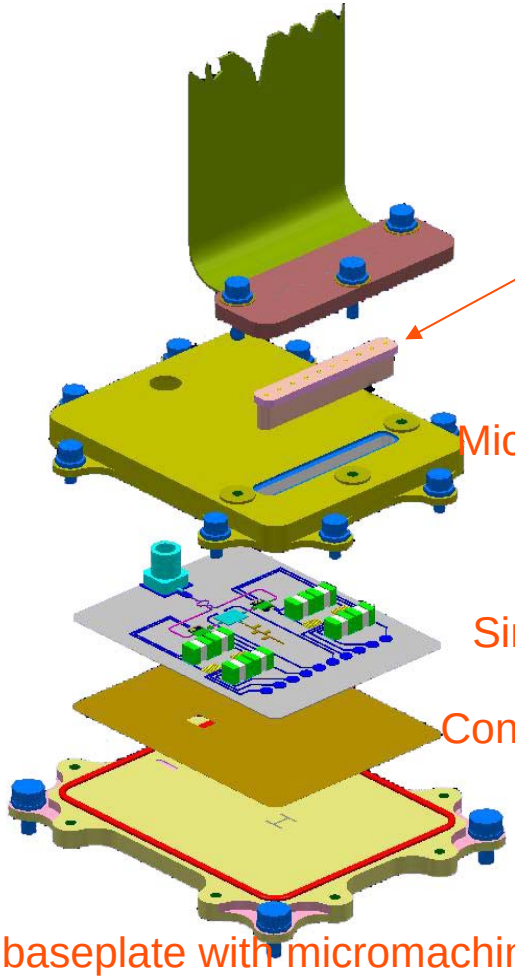
Design goals

- Minimize IL budget (2 dB between A and B)

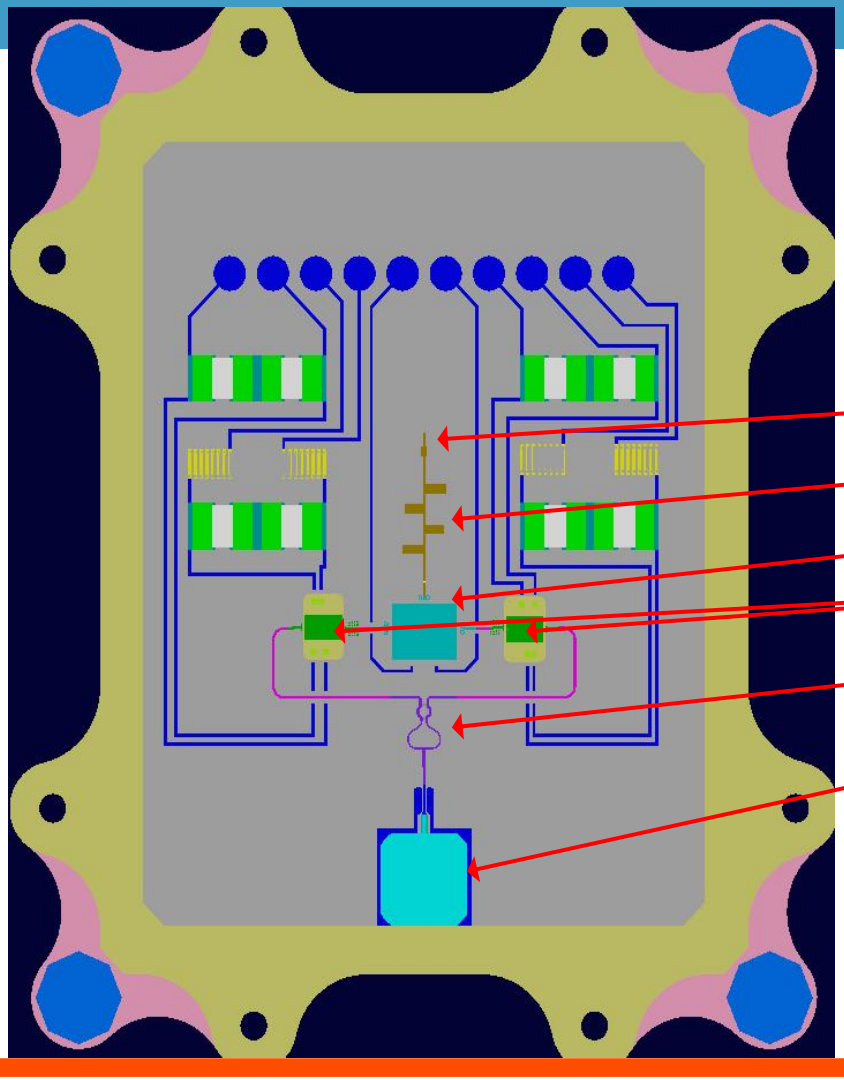


Same 3D stacking approach than the radiating part

- Conductive adhesive film/laser cutting
- Assembly and curing of the film using accurate pick and place equipment



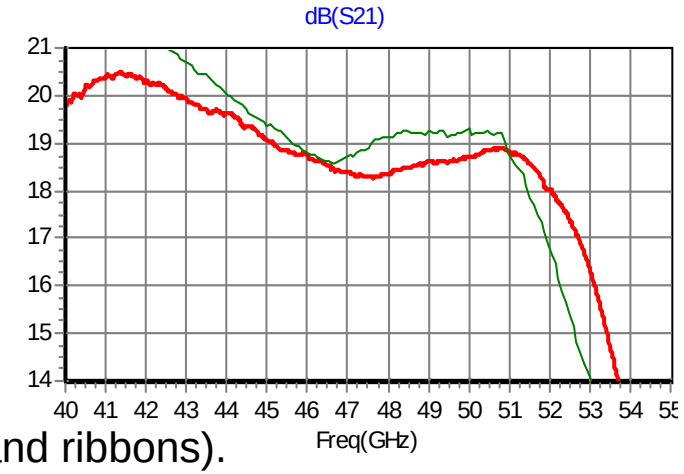
Close view of Alumina circuit



- RF circuit side
  - Alumina dimensions : 26 x 33.6 x 0.127mm
  - RF parts
    - antenna feed
    - Filter
    - SDPT (MEMS on Silicon)
    - 2 LNA (GaAs)
    - Wilkinson coupler
    - Mini SMP Connector/V connector

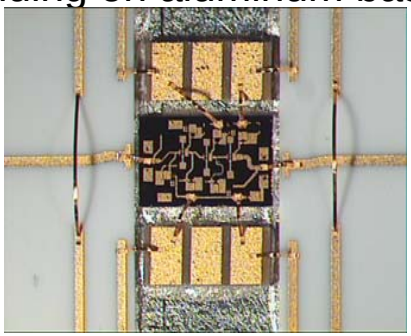
LNA 44GHz (COTS of UMS)

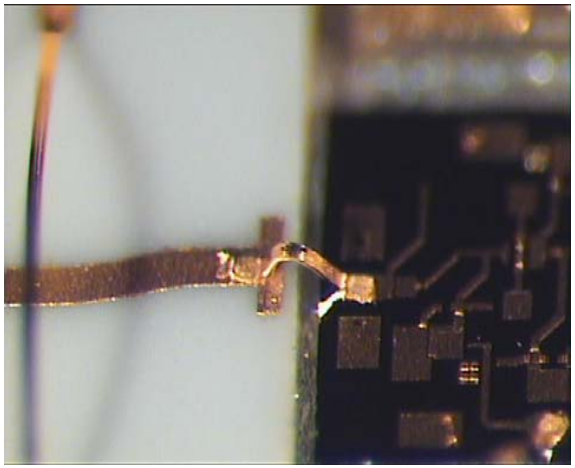
- Marketed frequency bandwidth : [36;44GHz]
  - MIPA project : [48;52GHz], typical measured linear gain 18 dB gain in the MIPA band
  - No tuning applied prior to measurements



Green – LNA before mounting in the module
Red – LNA mounted in the module (with 50Ωlines accesses and ribbons).

- Assembly topology
  - Au ribbon bonding to minimize parasitic inductance and die gluing on aluminum base plate





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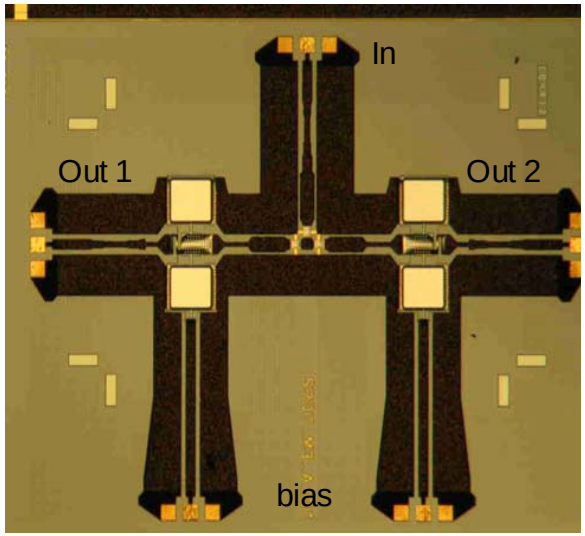
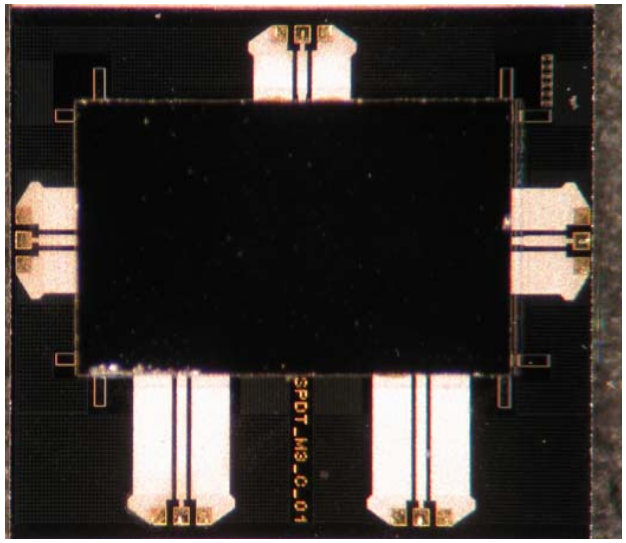
SPDT 50 GHz switch



Unpackaged device



Zero-level packaged device

- RF-MEMS technology
  - Capacitive in-line shunt switches
  - Separated biasing electrode
  - Compatible with mmwave application
- RF-MEMS packaging
  - Micromachined Si cap sealed with BCB

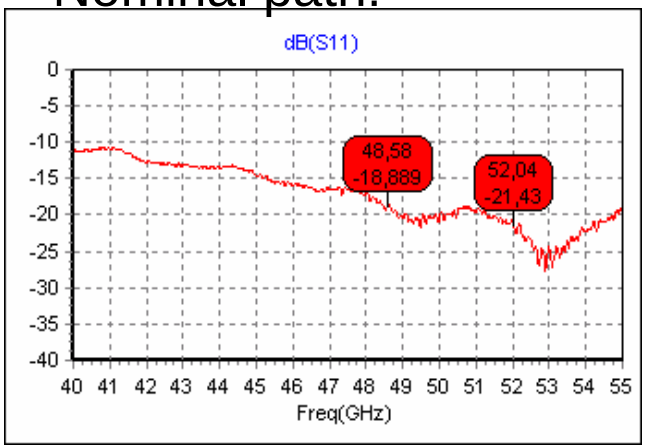
Packaged SPDT 50 GHz

- Packaged SPDT :

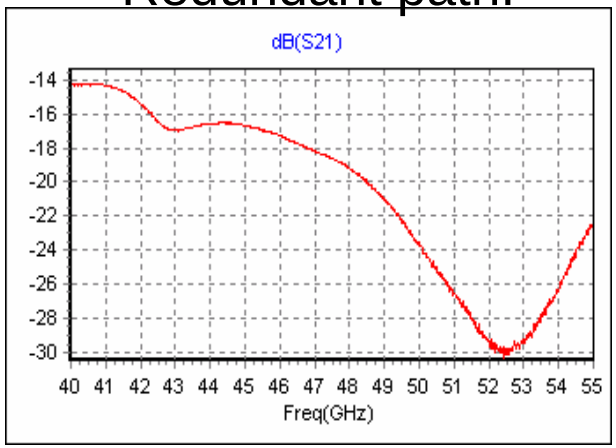
[48-52 GHz]

- S11 < –18.7 dB,
- S22 < -18.8 dB,
- Insertion losses S21< -1.35 dB with 0.2 dB flatness
- Isolation S21< -20 dB
- Vp 30 V

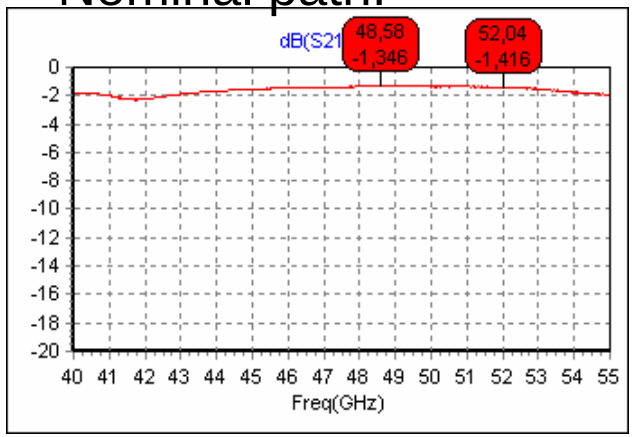
Nominal path:



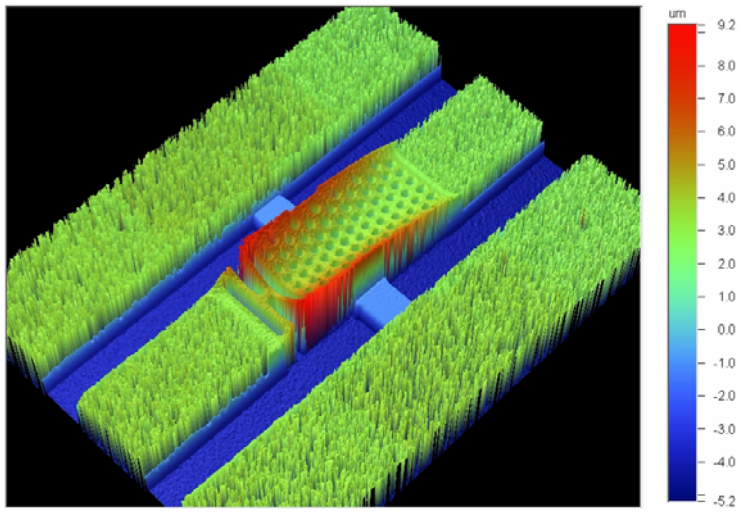
Redundant path:



Nominal path:

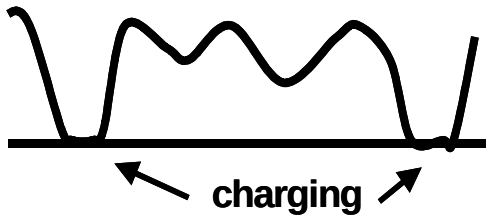


Reliability assessment

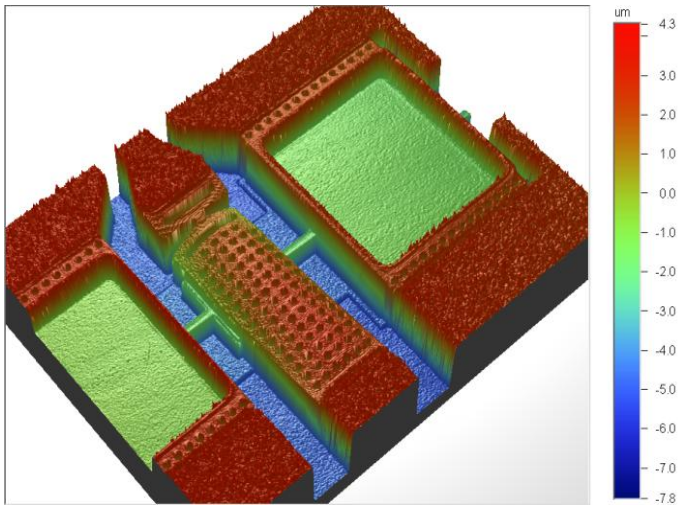


M1.24

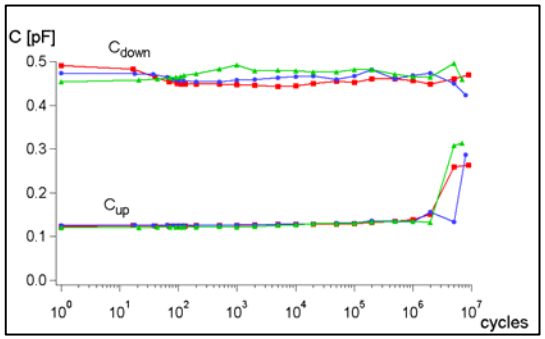
bridge response



Lifetime: 1 cycle

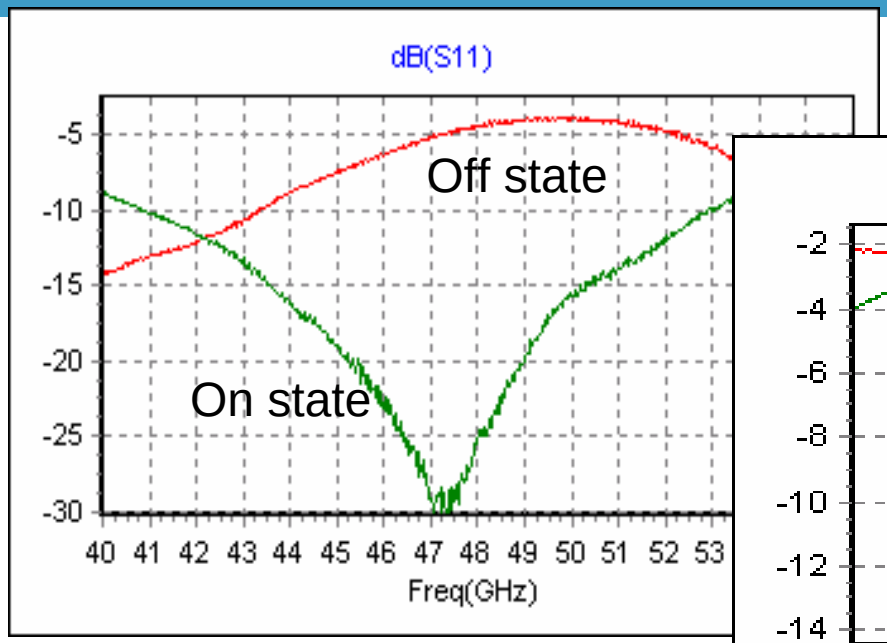


M3.17

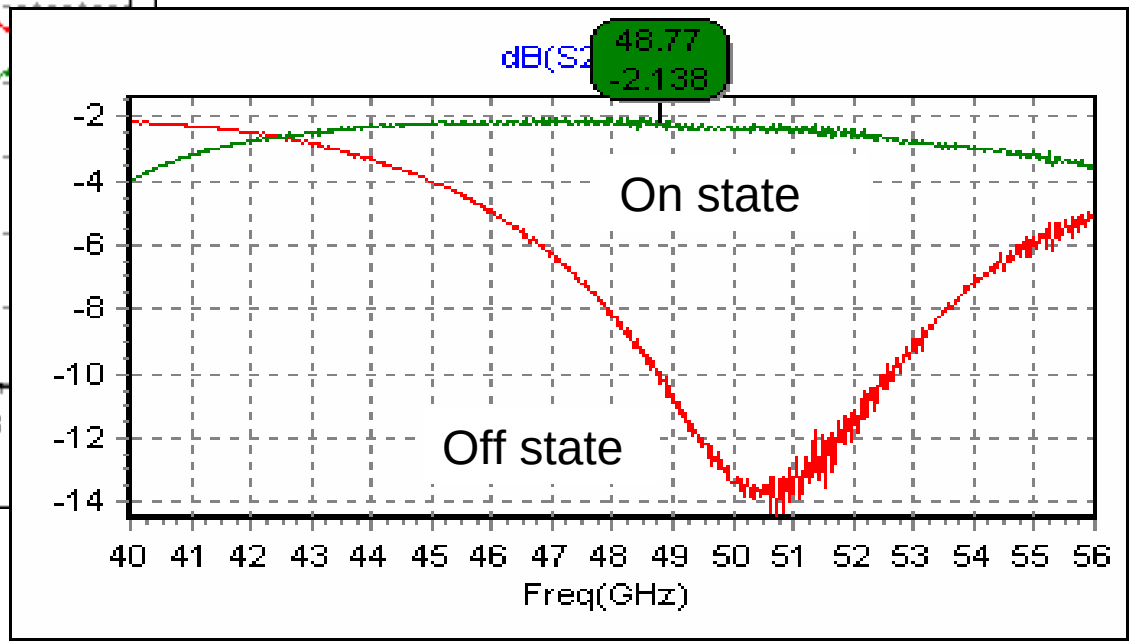


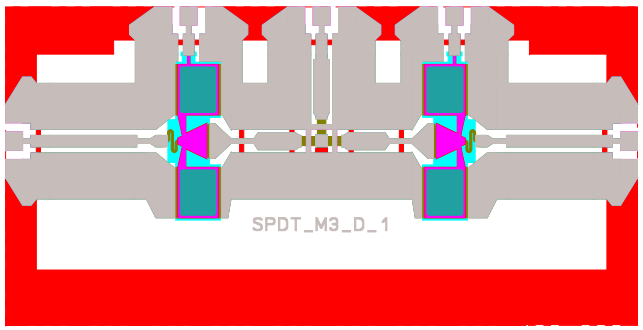
Lifetime: 10^6 – 10^7 cycles

SPDT testing prior to mounting



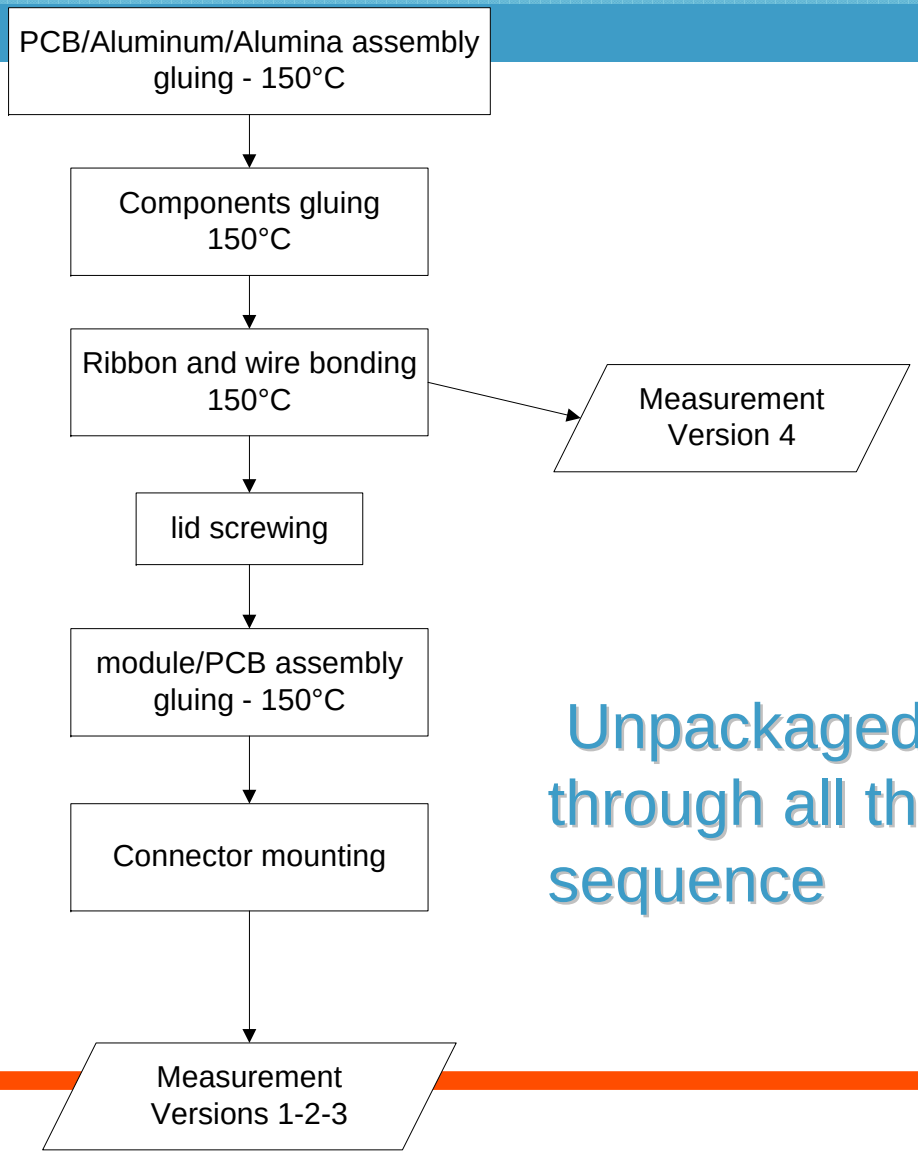
Unpackaged SPDT, type A, Vpin=35 V





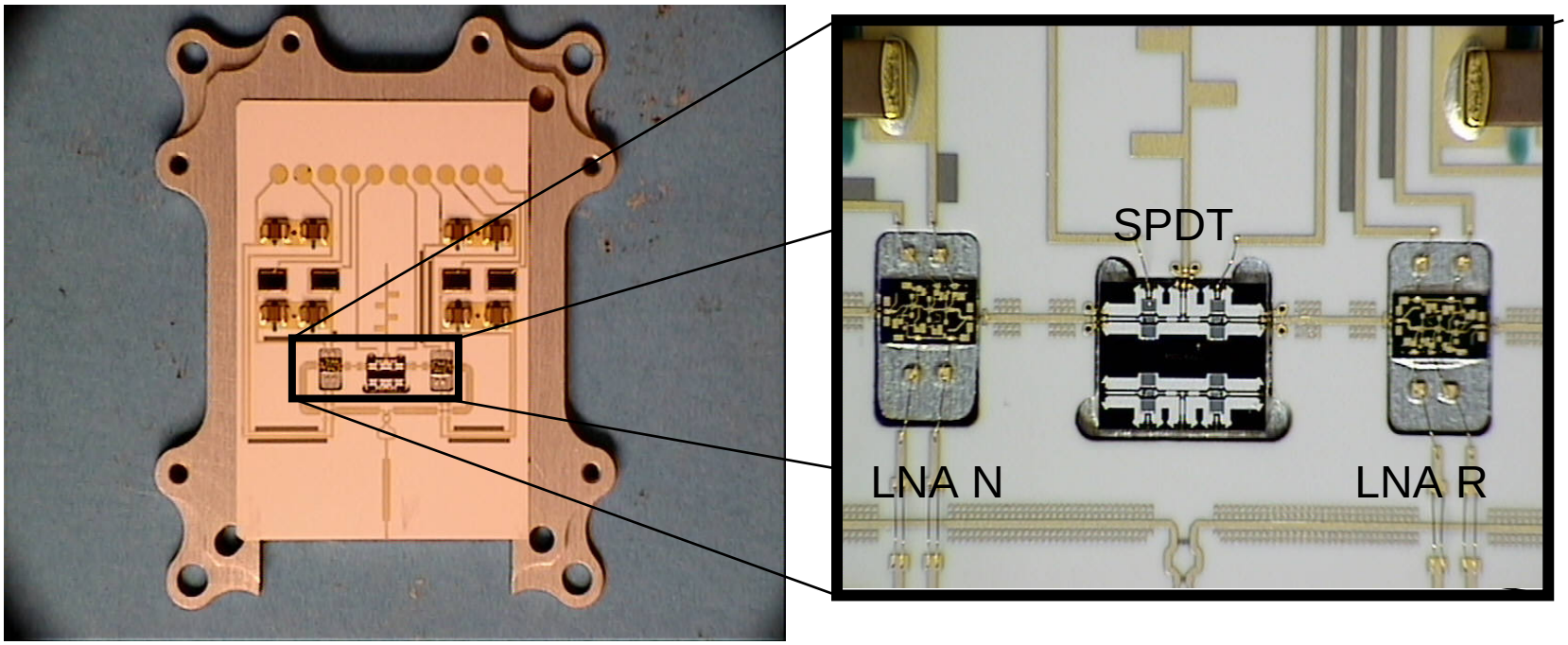
Devices selected for hybridation into the active feed antenna

Manufacturing



Unpackaged SPDT went through all this fabrication sequence

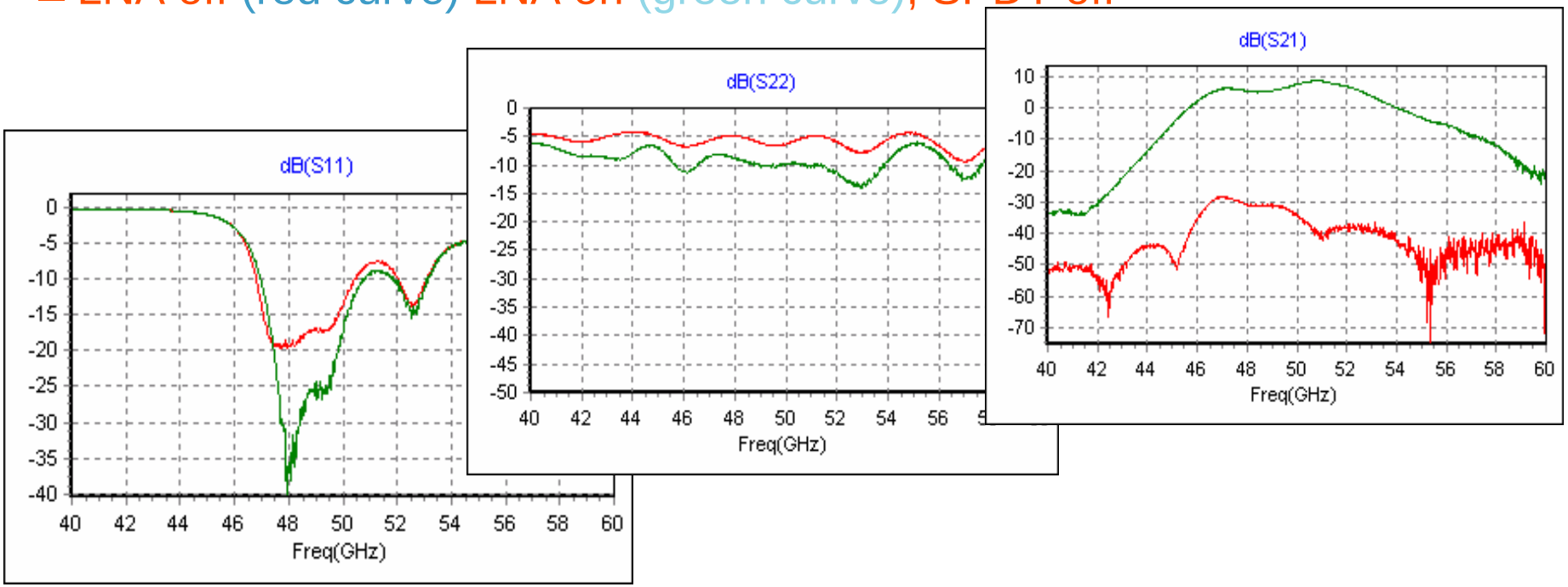
Manufacturing of antenna prototype



Microwave circuit side

Test results on microwave circuit part

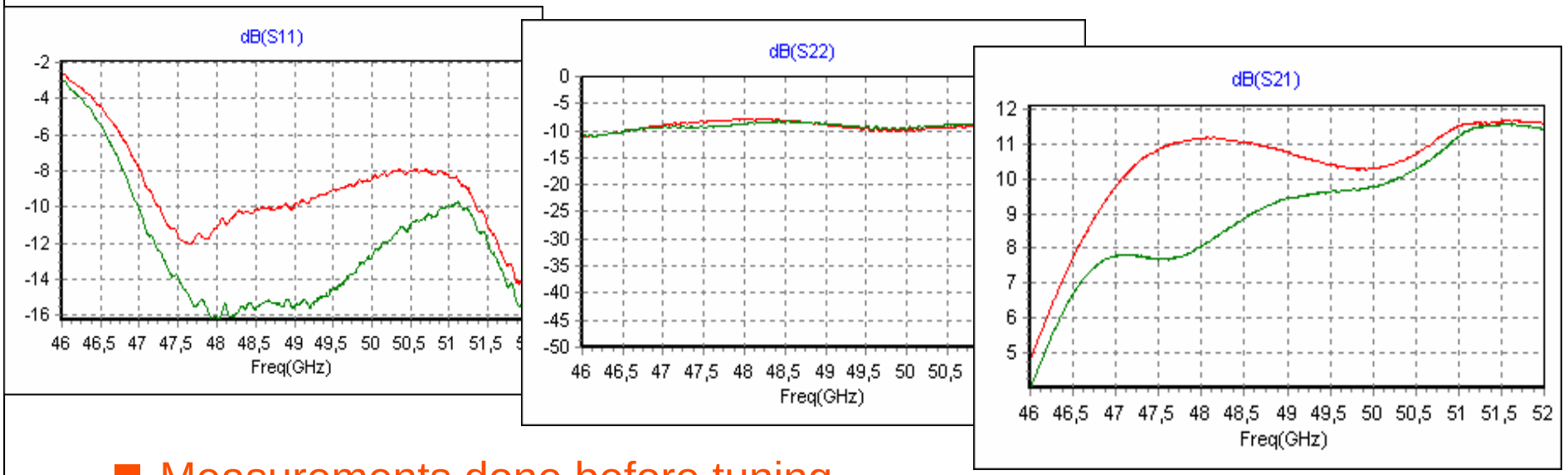
- LNA off (red curve) LNA on (green curve), SPDT off



- Input matching (<-15 dB) and output (-10 dB) matching within specifications on the 47.2-50.2 GHz band
- Rejection of Tx band 38-42 GHz, better than -30 dB
- No inner-band and outer band spurious

Test results on microwave circuit part

- LNA N on SPDT off (green curve), LNA N on, SPDT on (red curve)



- Measurements done before tuning
  - Linear gain of about 10.5 dB on the 47.2-50.2 GHz band, ripple <-1 dB
  - Loss budget at 48.7 GHz : Filter –1 dB (simulation), SPDT –3 dB, Wilkinson coupler –3.5 dB, interconnect losses –1.5 dB, LNA gain 18 dB

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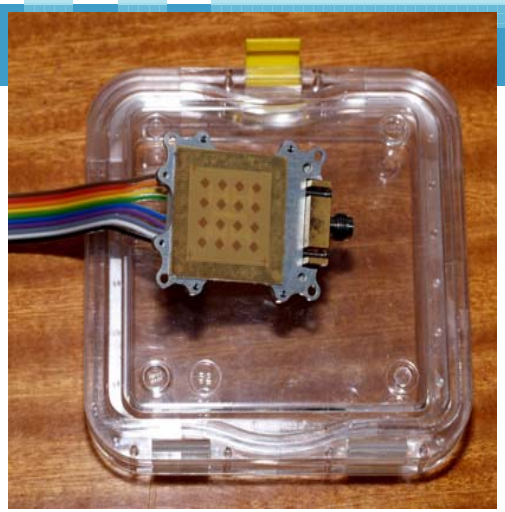
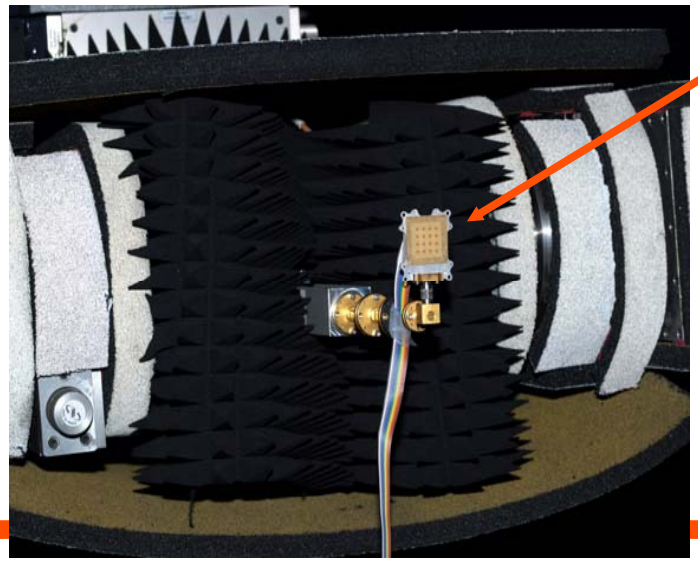
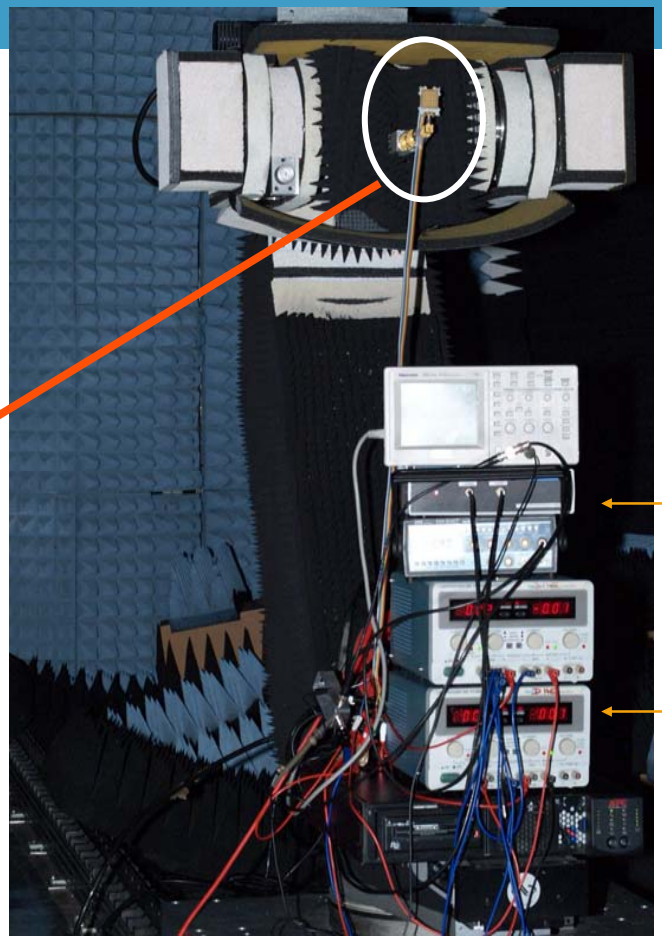
MEMS based active antenna feed



Active antenna with bias connector



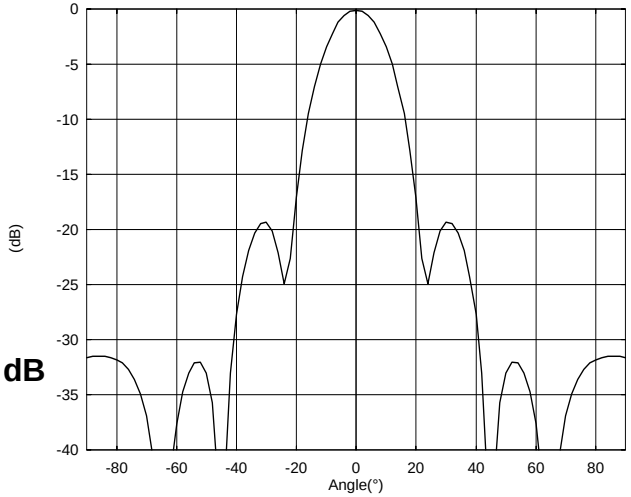


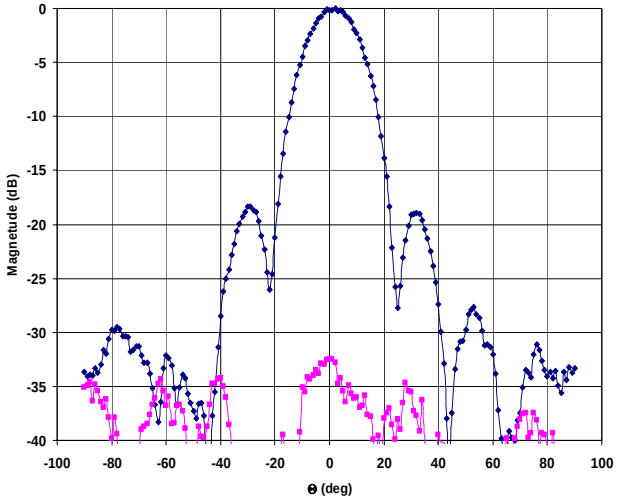
Active feed antenna measurements

H plane, model vs measurements

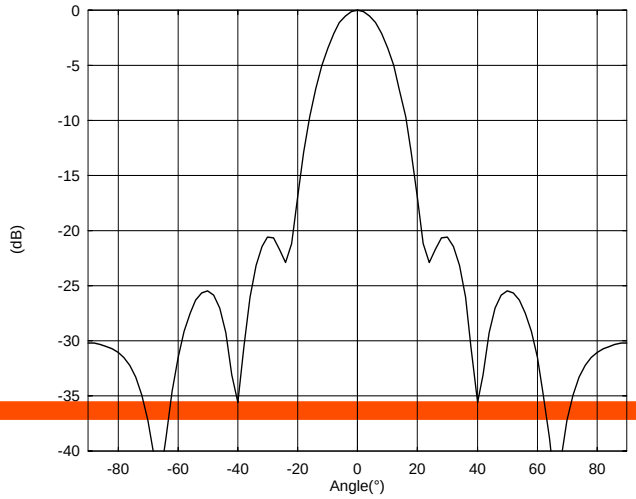
H Plane at 48.7 GHz

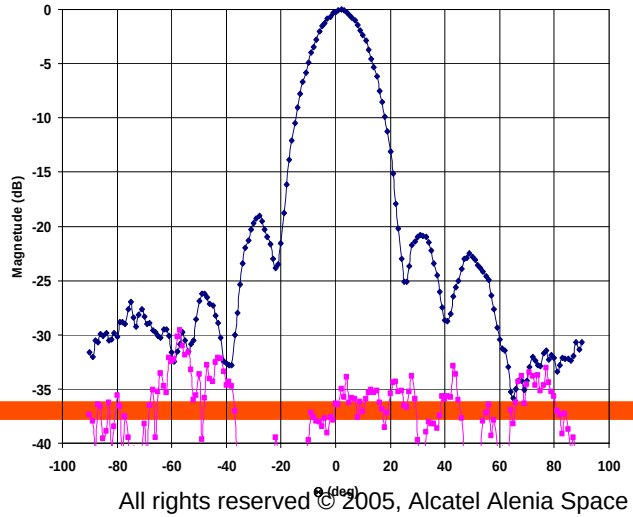
Beamwidth : 19°
Sidelobes level : -20 dB
Cross polarization : < -33 dB





H Plane at 50.2 GHz



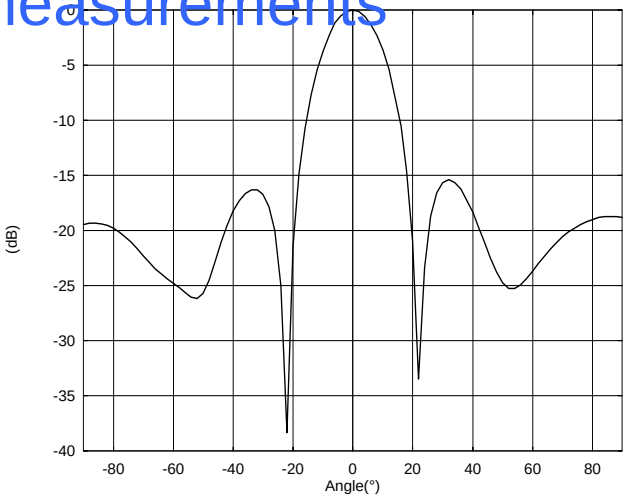


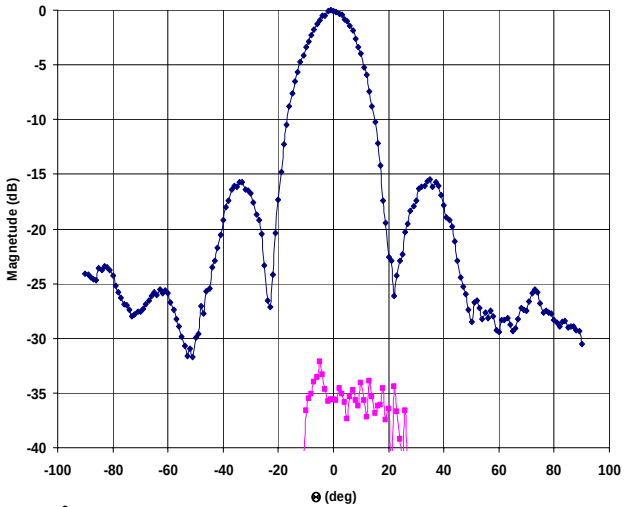
Active feed antenna measurements

E plane, model vs measurements

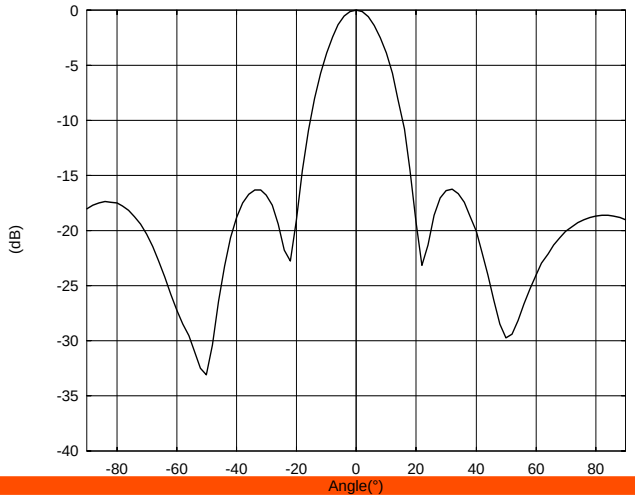
E Plane at 48.7 GHz

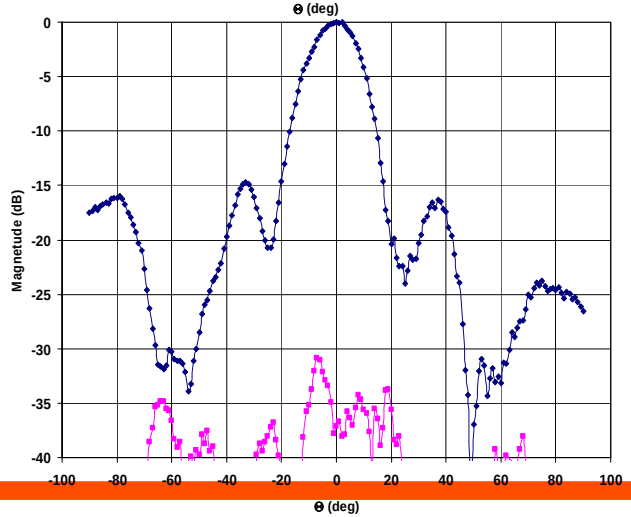
Beamwidth : 20°
Sidelobes level : -15 dB
Cross polarization : < -33 dB





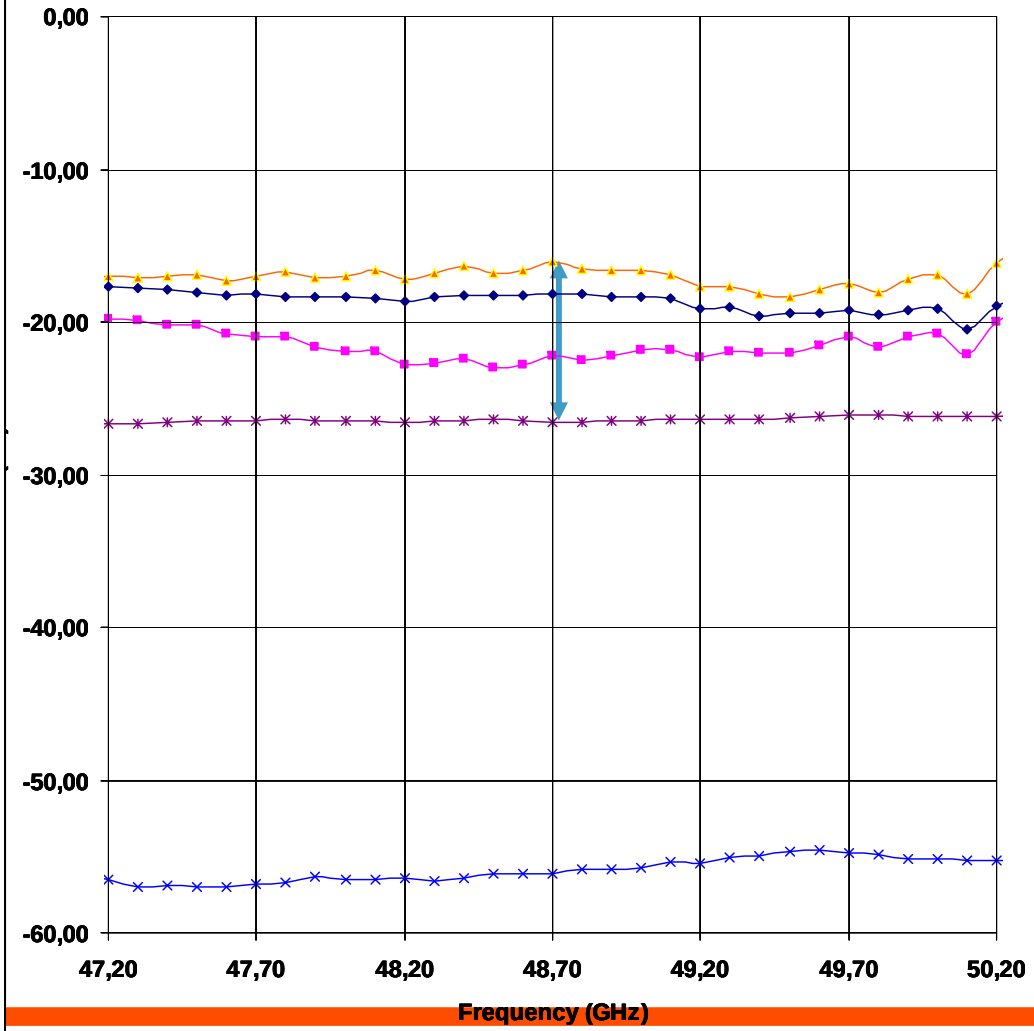
E Plane at 50.2 GHz





Active feed antenna measurements

Received power



Active/Passive antenna gain ≈ +10dB

LNA gain ≈ 18dB
SPDT Loss ≈ -2dB
Filter Loss ≈ -1dB
Bondings loss ≈ -1.5dB
Wilkinson loss ≈ -3.5dB

_____

Total gain ≈ +10dB

Total active antenna gain ≈ 26.5 dB

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Conclusions

- V band compact active feed have been demonstrated
  - 3D integrated active antenna architecture (26x33x7 mm3)
  - Use of MEMS SPDT for LNA module redundancy
  - Use of bulk micromachining (UV laser and/or electro-erosion techniques)
  - Use of material and processes compliant with space environment
- Missing
  - G/T measurements (on-going)
- Future
  - Monolithic integration of MEMS SPDT onto the microwave passive circuit
  - Embedded micro heat pipes into the metal base plate for thermal management

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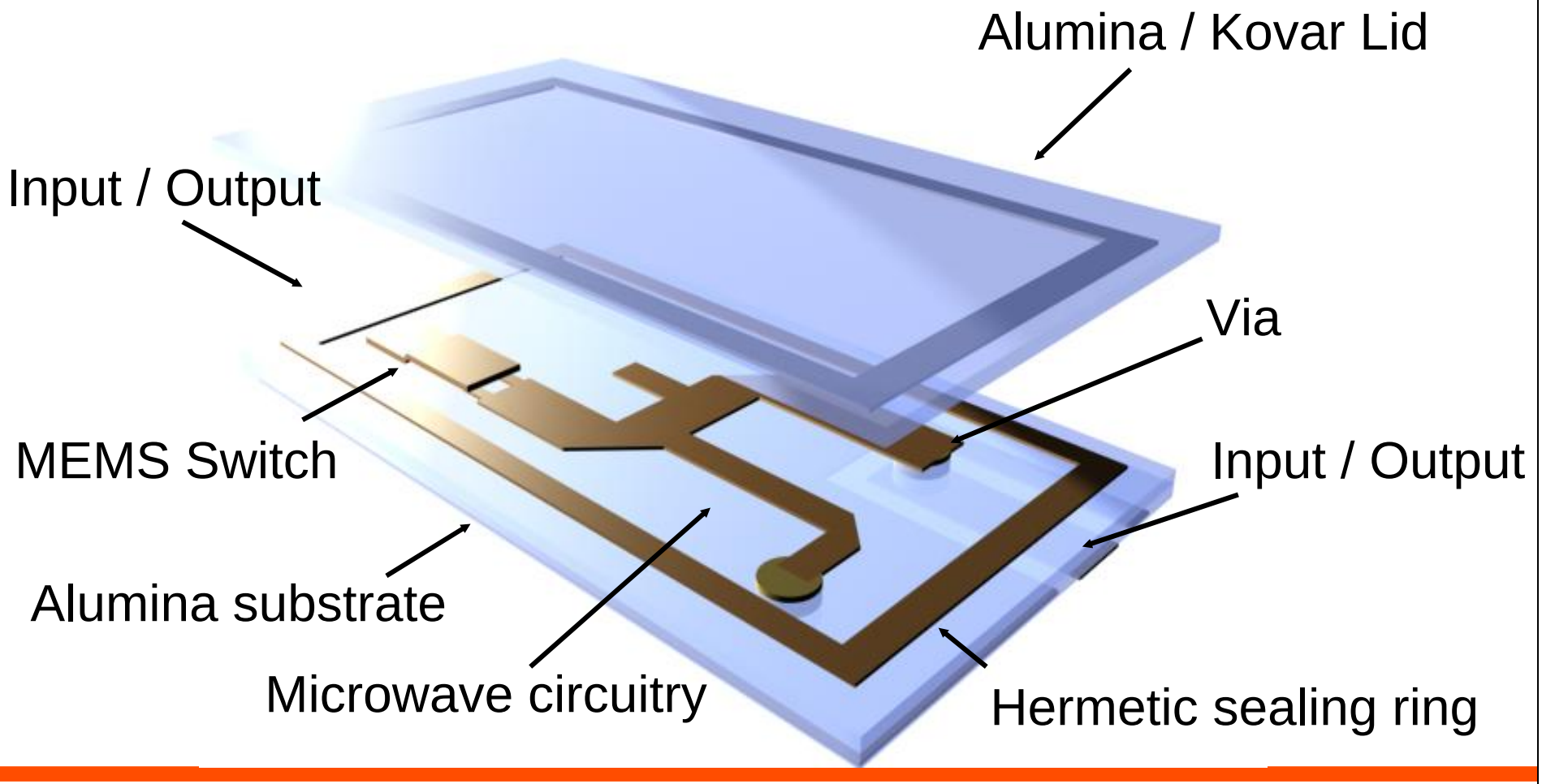
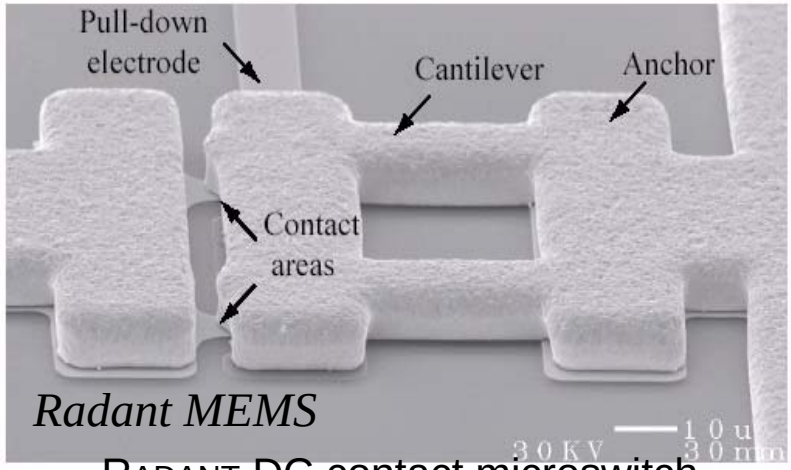
We need to think smarter….



And faster…

RADANT MEMS Commercial Switching devices



RADANT DC contact microswitch

RADANT has already demonstrated switch life time of 250 billion switching cycles in cold switching operation

<u>RADANT switch offers</u>

Excellent RF performances

- An hermetic on wafer level package technology
- > 10 Billion cycles life time under 0.5 W of power
- A price closed to 5$ per switch

Hermetic packaged device

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RF MEMS Reliability ?

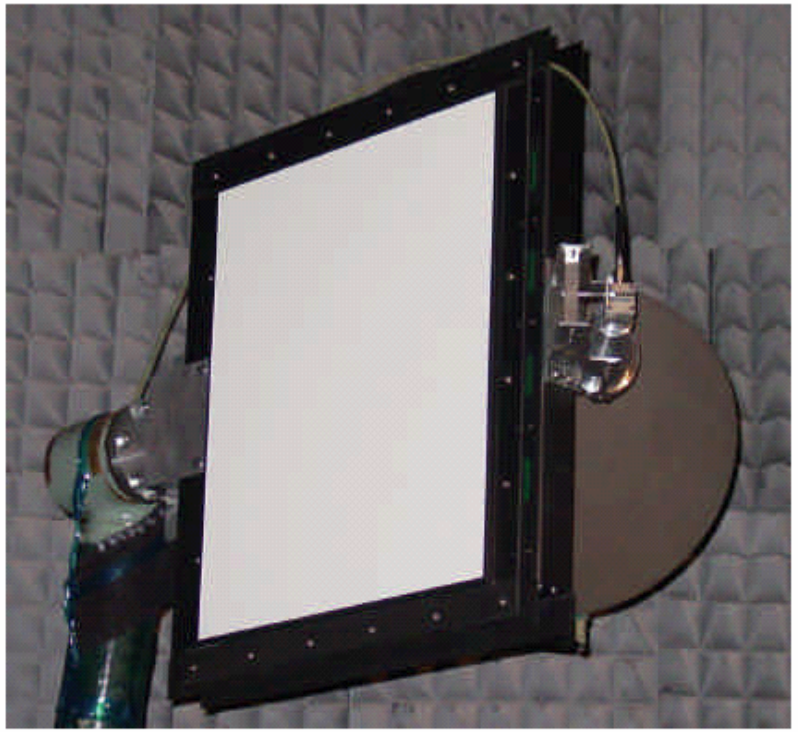
Developed by Radant Technologies for AFRL/Hanscom AFB

0.4m² Fire Control Radar Antenna

- **X-Band with 60 Deg. of Scan**

MEMS Switches

- **40,000 MEMS Fab and Tested**
- **25,000 MEMS Installed**
- **First Large Scale use of MEMS in an ESA**



25,000 MEMS Switches Reliably Employed in a Functional Electronically Steerable Antenna

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Acknowledgments

- European Commission for funding of IST MIPA project
- All the MIPA partners