A G-Band 160 GHz T/R Module Concept for Planetary Landing Radar

Lorene Samoska, Pekka Kangaslahti, David Pukala, Gregory Sadowy, Brian Pollard, and Richard Hodges

Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA (USA) 91109

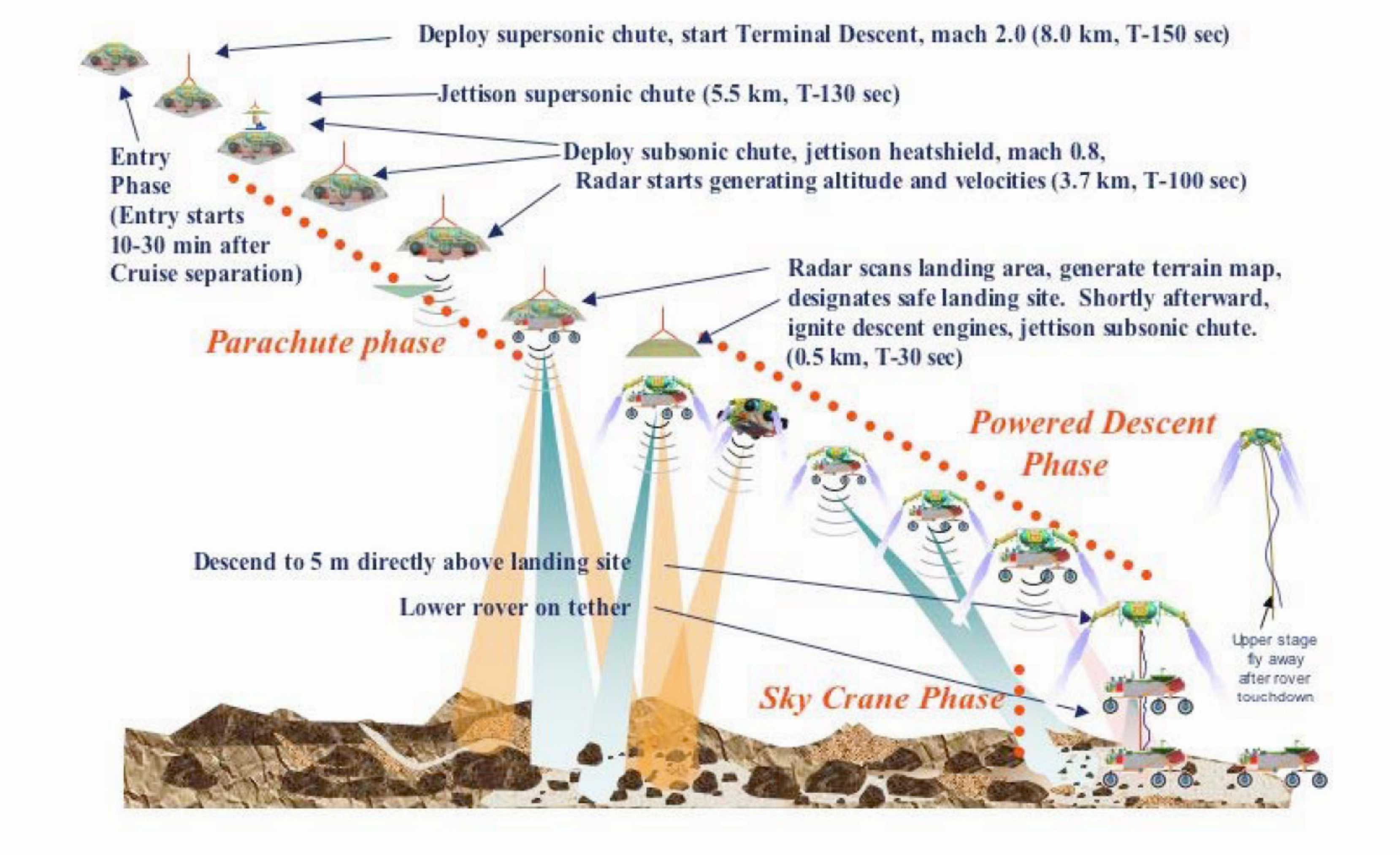
Outline

- Introduction
- Why G-Band for landing radar?
- MMIC Components:
  - Power amp module results to date
  - Low noise amp (LNA) results to date
  - T/R module SPDT switch
- Antenna and interfaces
- Summary

Motivation

- G-Band (160 GHz) proposed for landing radar
- Higher frequency means better resolution
- Smaller Antenna size, lower mass
- MMIC components enable a radar array
- Interfacing to a Continuous Transverse Stub (CTS) Antenna makes it compact
- Other applications for G-Band components include automotive radar, millimeter-wave imaging, commercial test equipment, and ground-based telescope receiver components

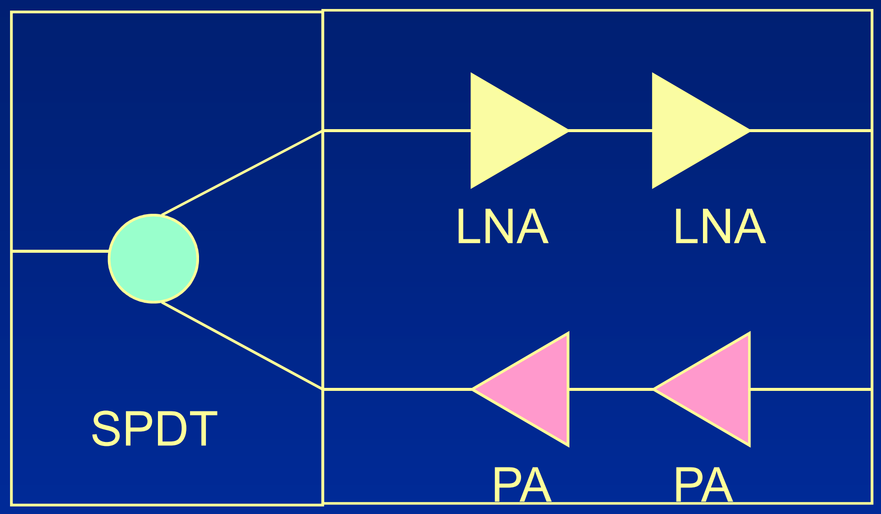
Entry Descent and Landing



B. D. Pollard and G. Sadowy, "Next Generation Millimeter-wave Radar for Safe Planetary Landing," *2005 IEEE Aerospace Conference,* March 5-12th, 2005, pp. 1-7.

[3] E.C. Wong, G. Singh, J.P. Masciarelli, "Autonomous guidance and control design for hazard avoidance and safe landing on Mars (AIAA-2002-46192)," *Proceedings of the 2002 AIAA Atmospheric Flight Mechanics Conference,* Monterey, CA, August 2002.

Functional Blocks of T/R Module



SPDT= Single Pole Double Throw Switch

PA = Power Amp

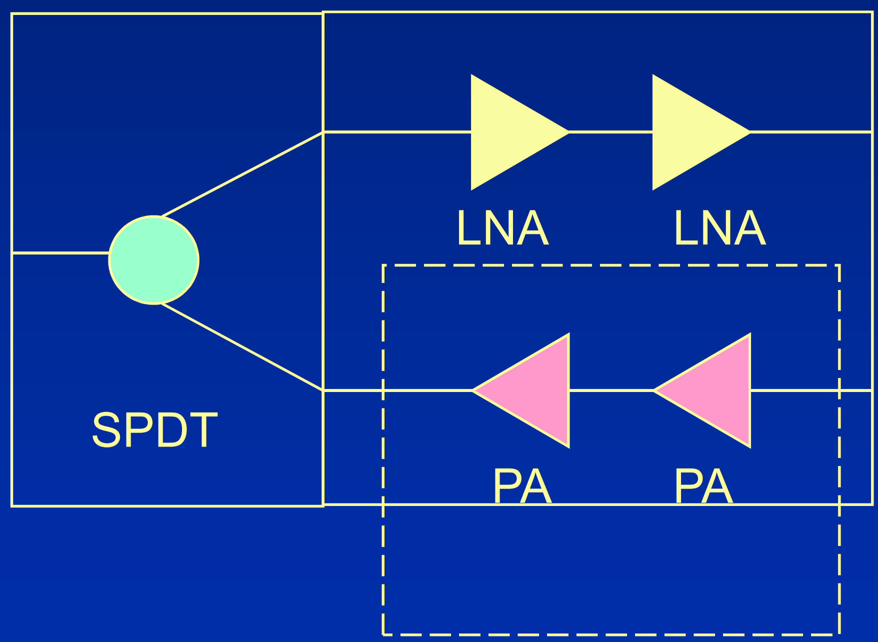
LNA = Low Noise Amp

Goals:

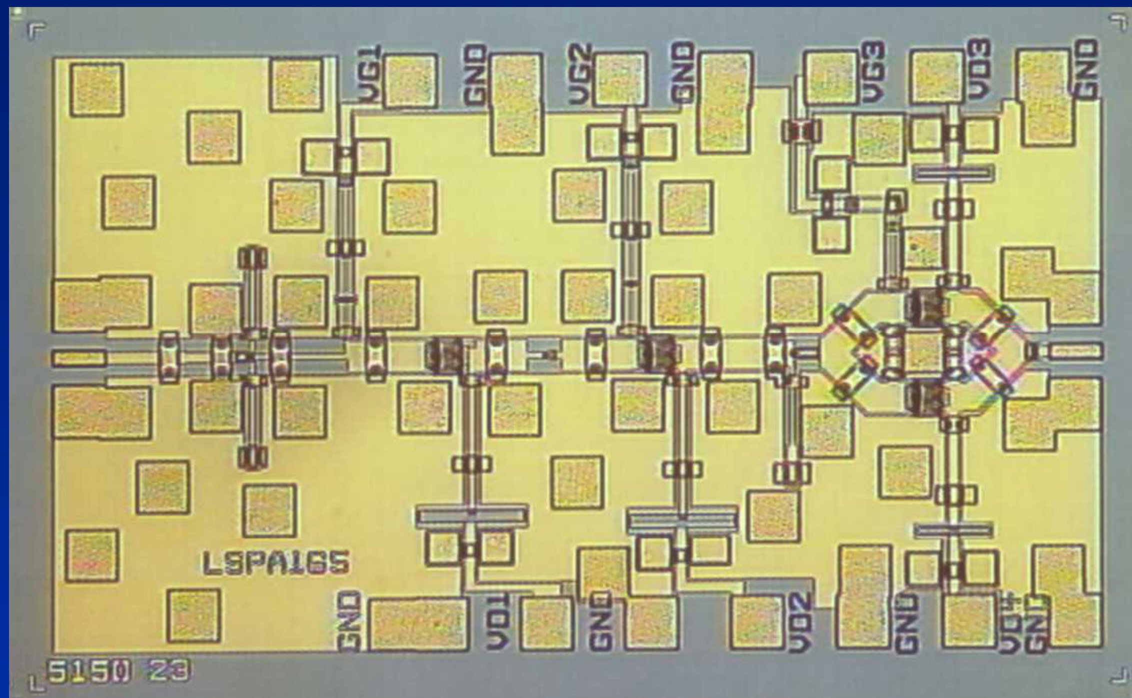
PA: 10-13 dBm

LNA: 8 dB NF

G-Band Power Amplifier MMICs



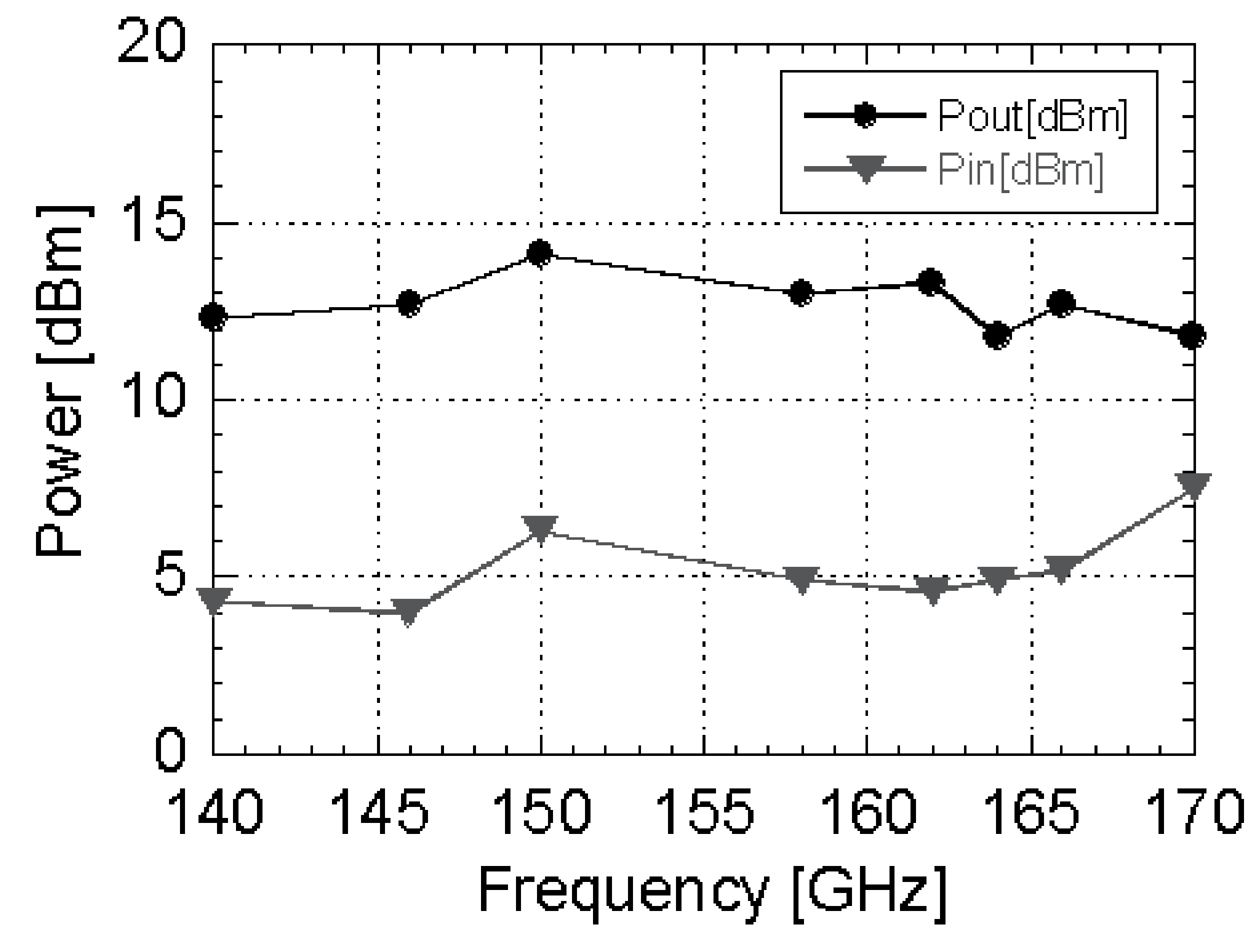
140-160 GHz Driver Amp



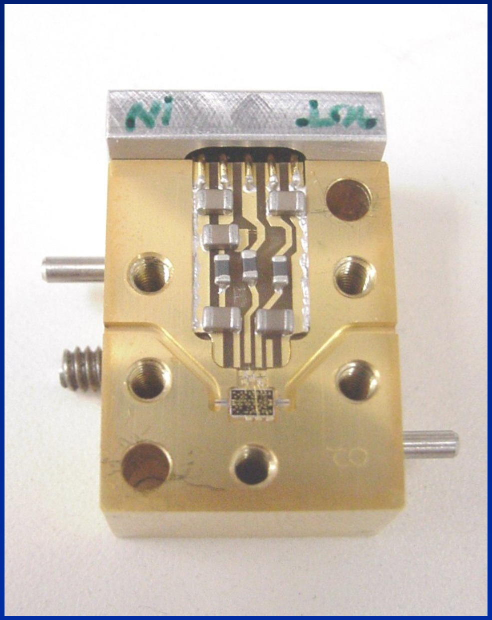
- 3-stages: InP HEMT fabricated at HRL Labs
- Output periphery 300 μm.

Reference: L. Samoska, IEEE MWCL, 2003

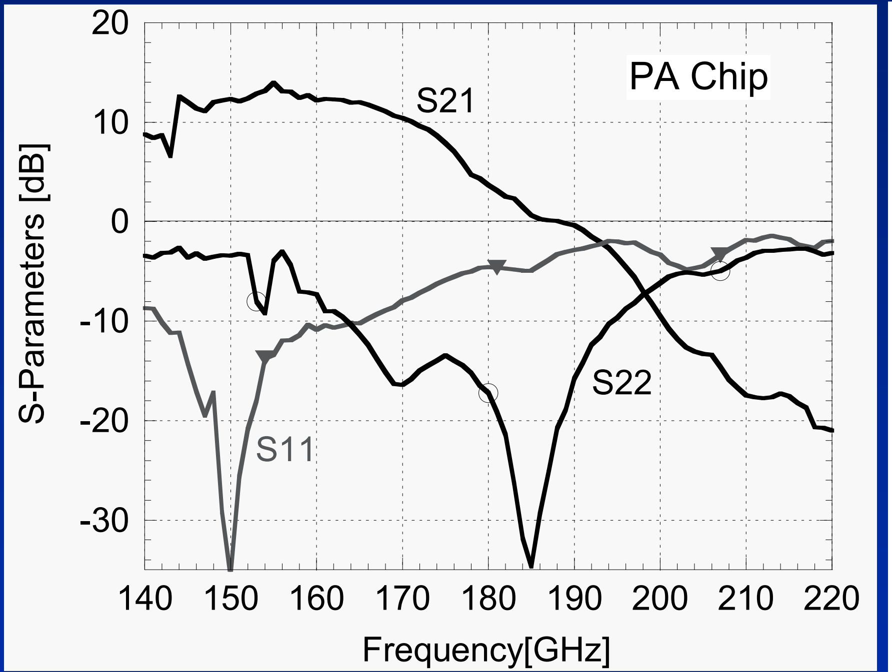
Output Power vs Frequency



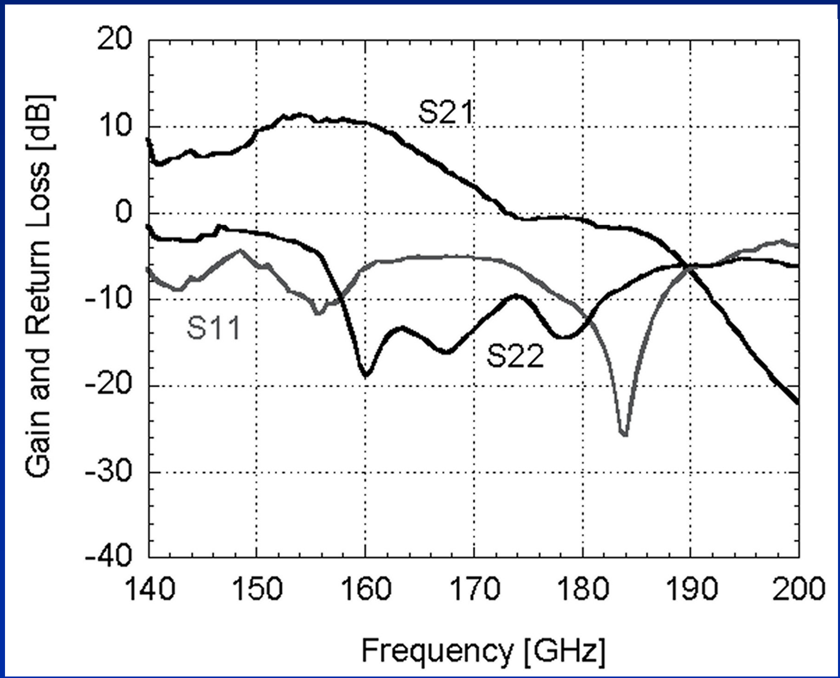
WR5 PA Module



S-Parameters of PA Chip and Module

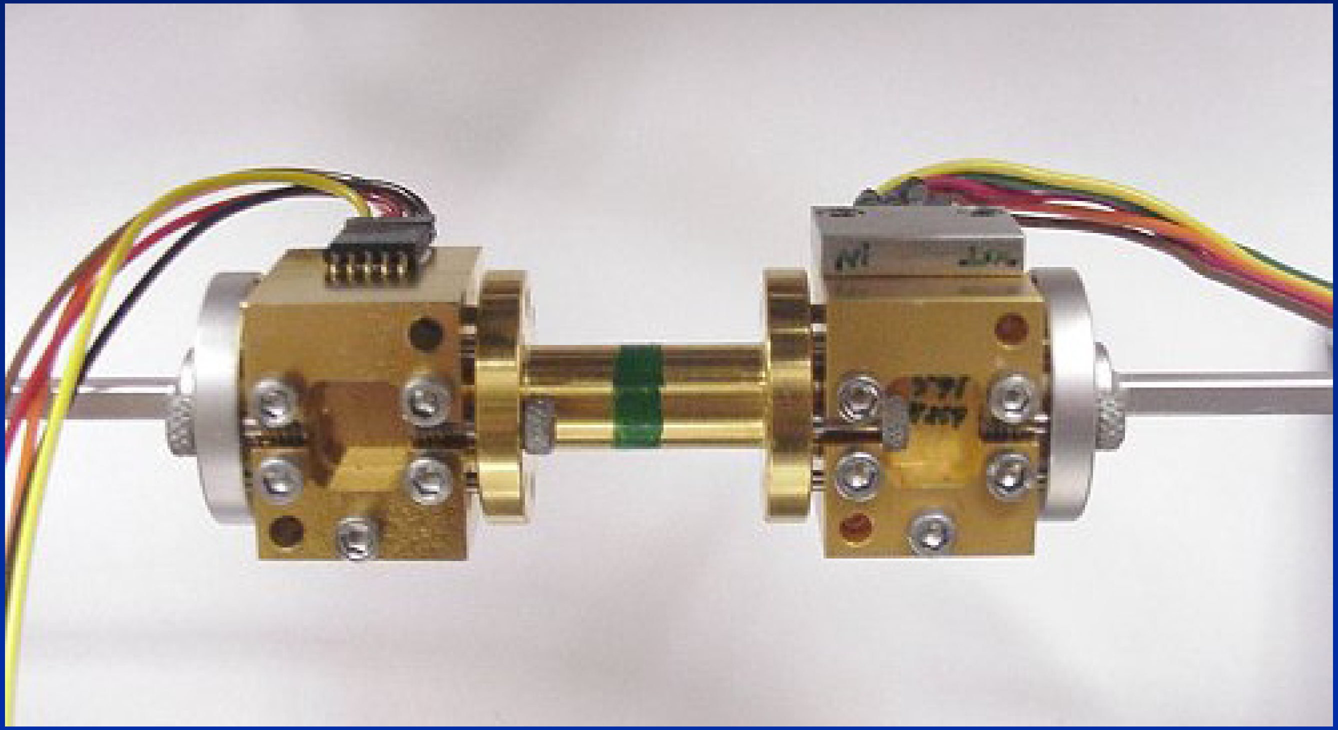


Chip Only

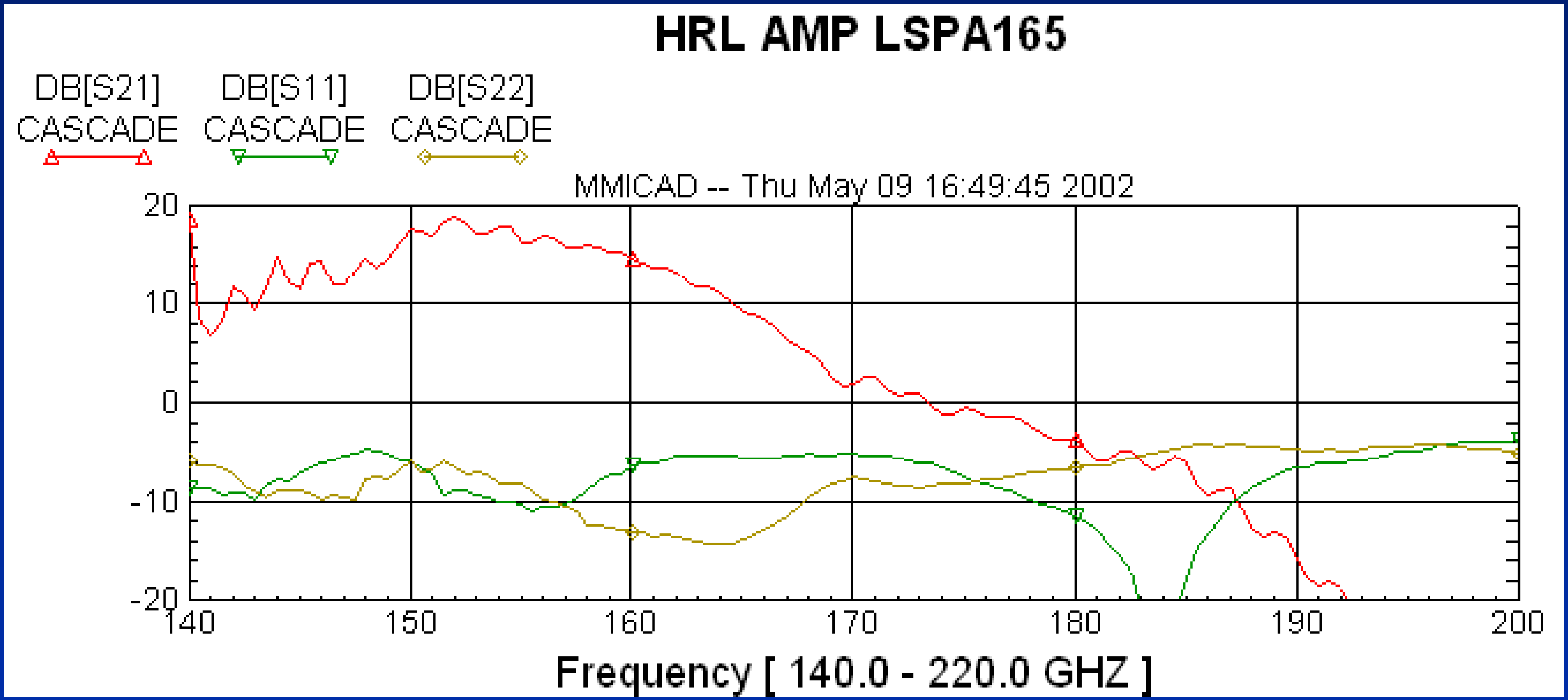


WR5 Module

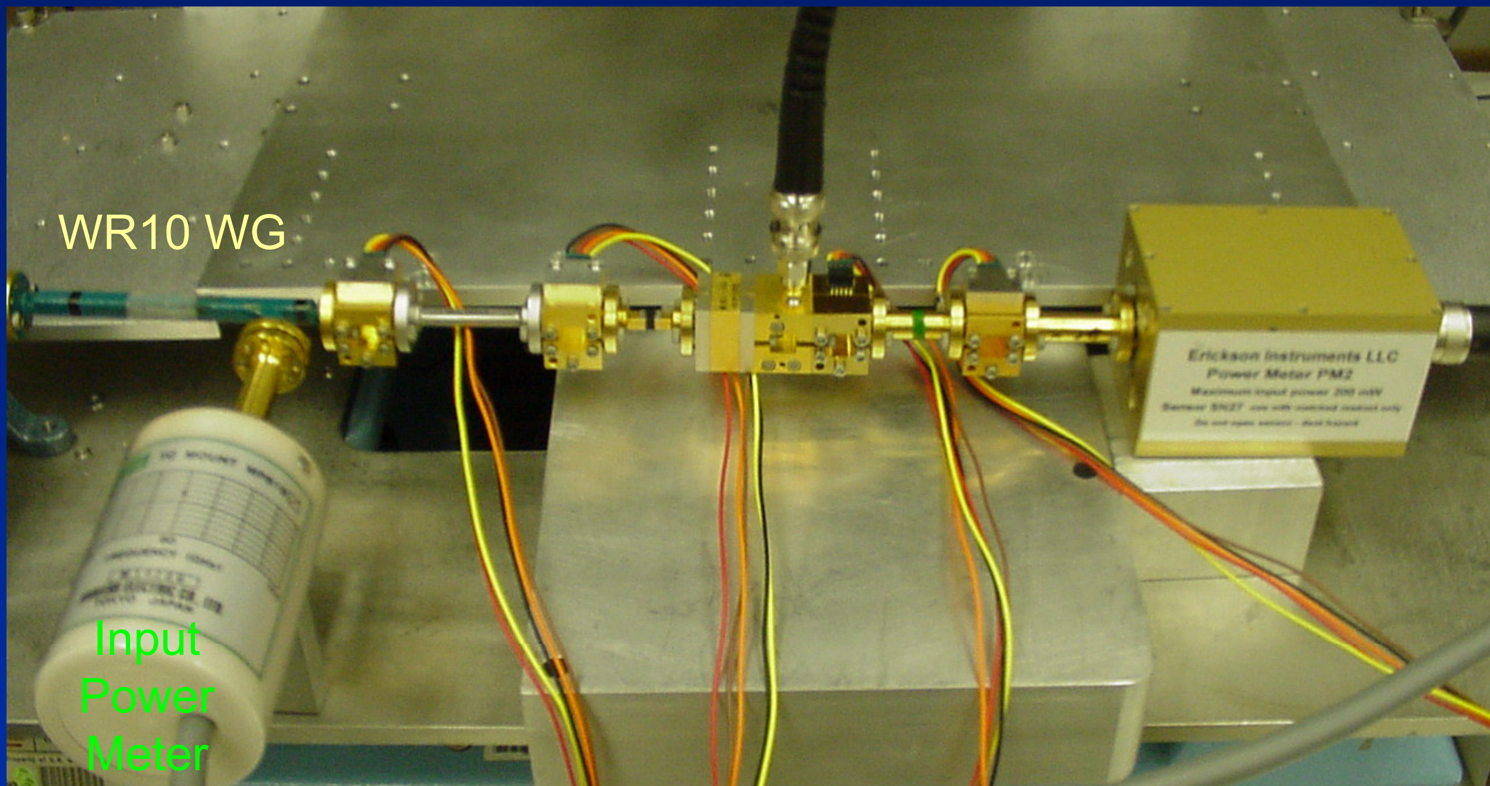
Cascade photo

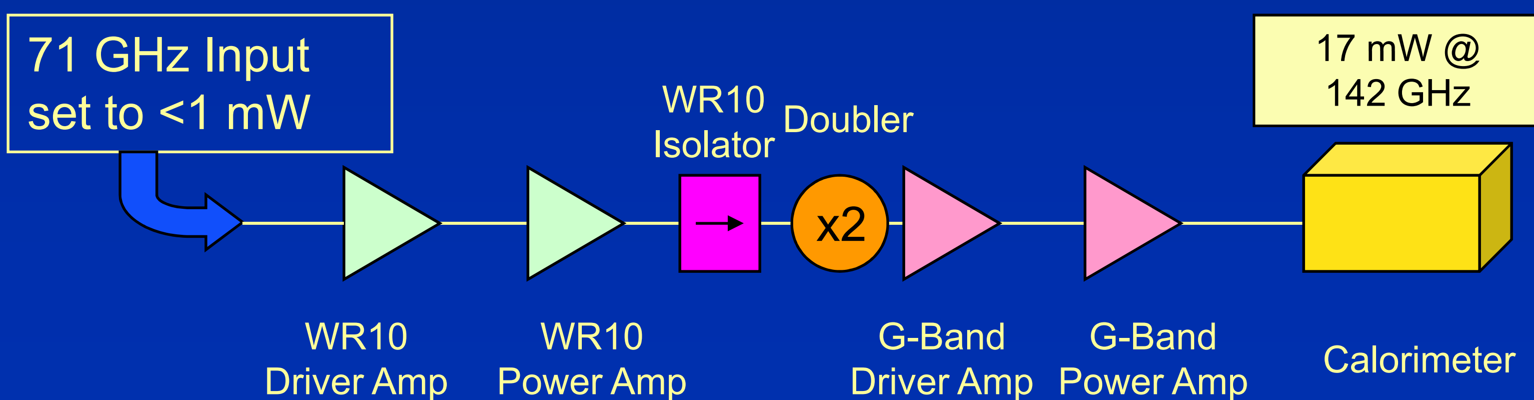


S-parameters

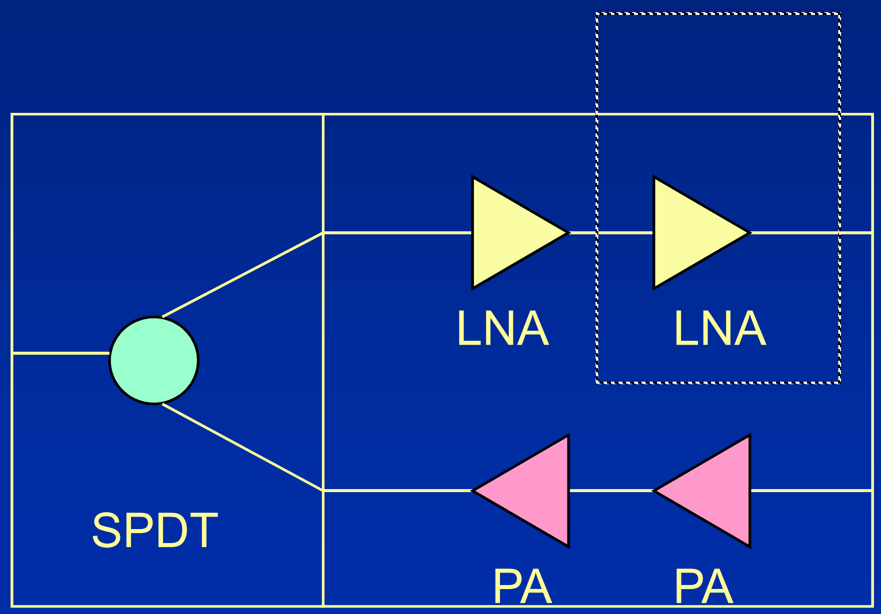


G-Band PA Cascade Test

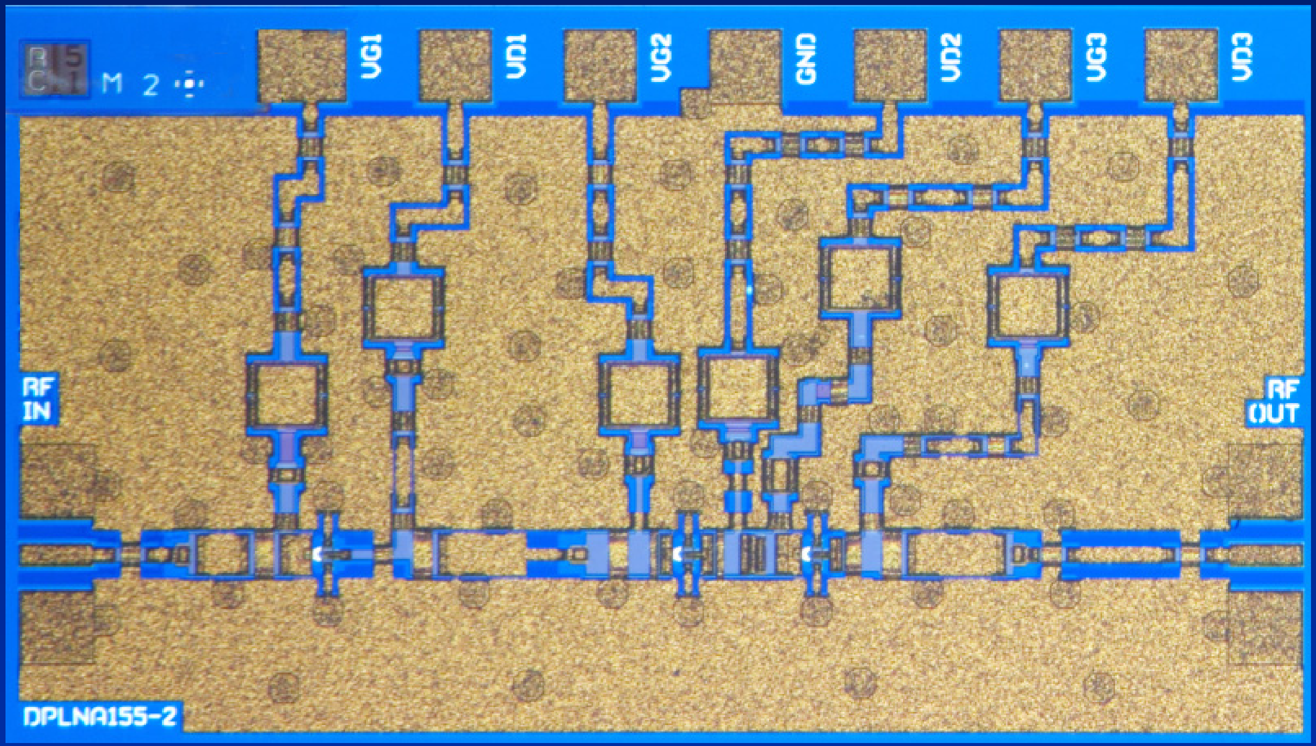




Low Noise Amps

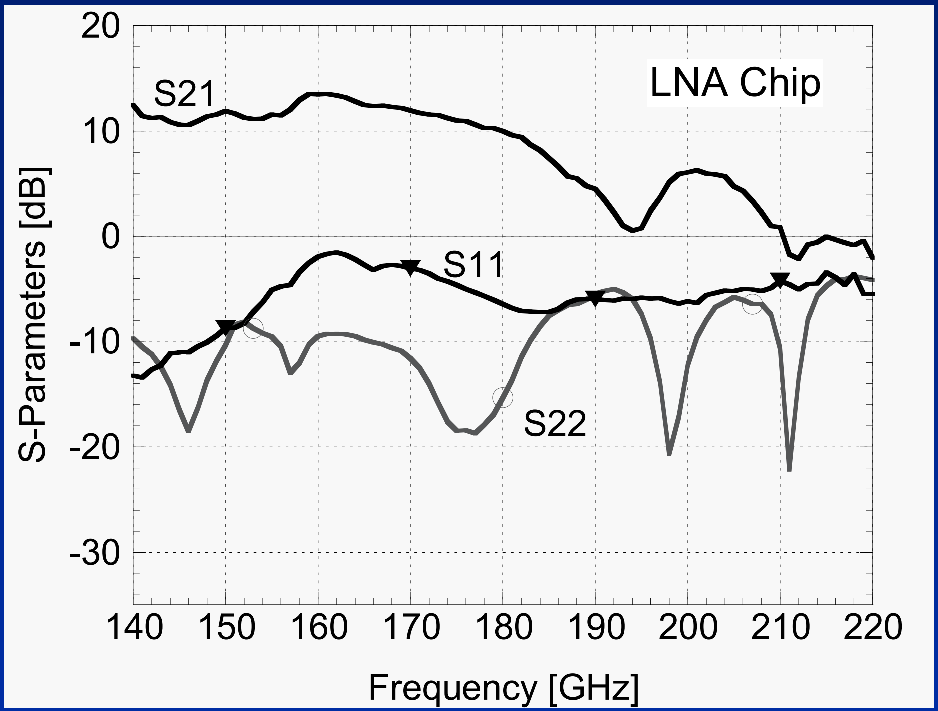


MMIC Low Noise Amplifier

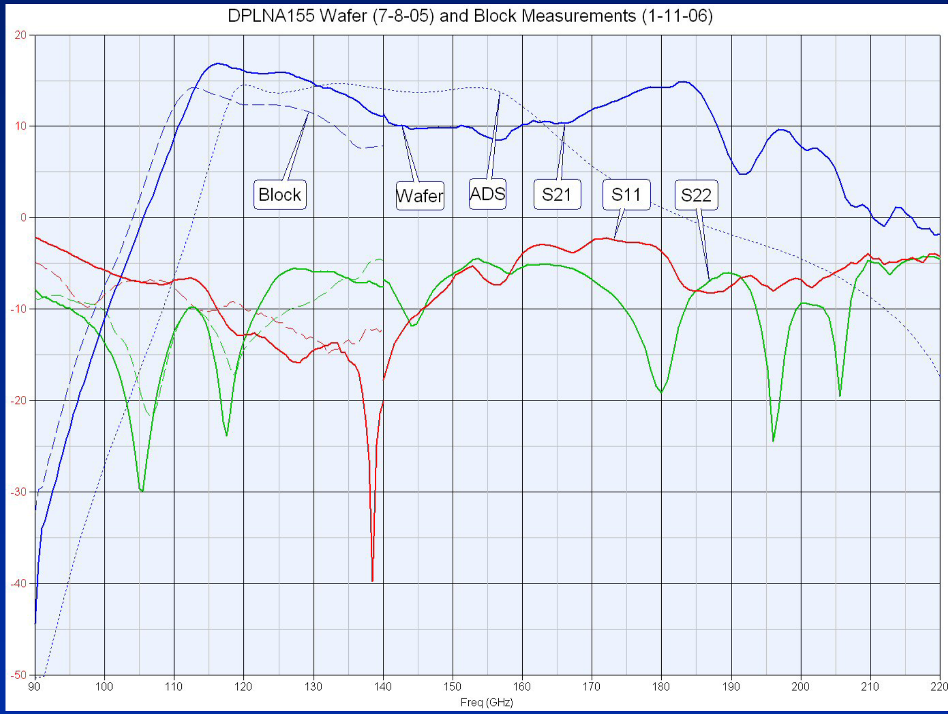


Fabricated at NGST using 2f30 InP 70 nm HEMT devices

S-Parameters of Low Noise Amp MMIC

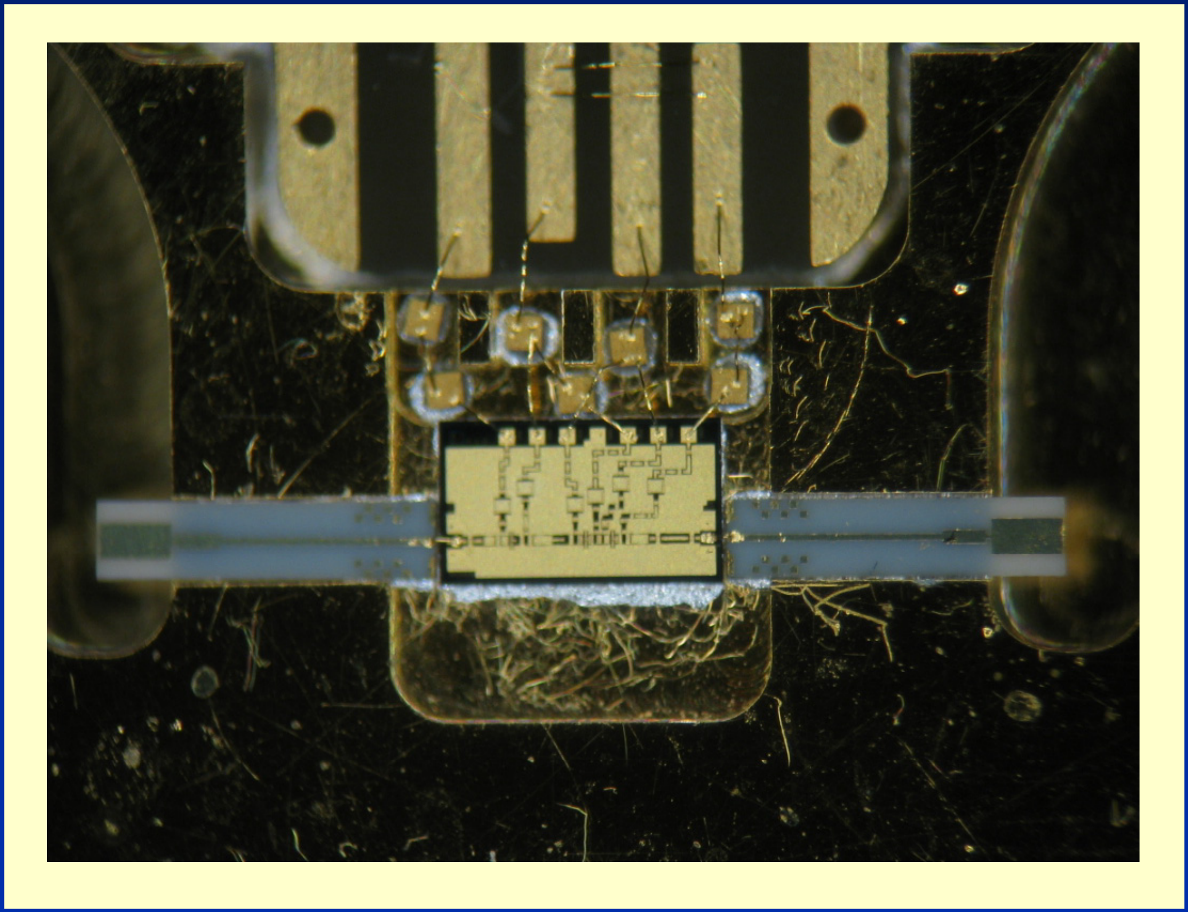


Chip-only

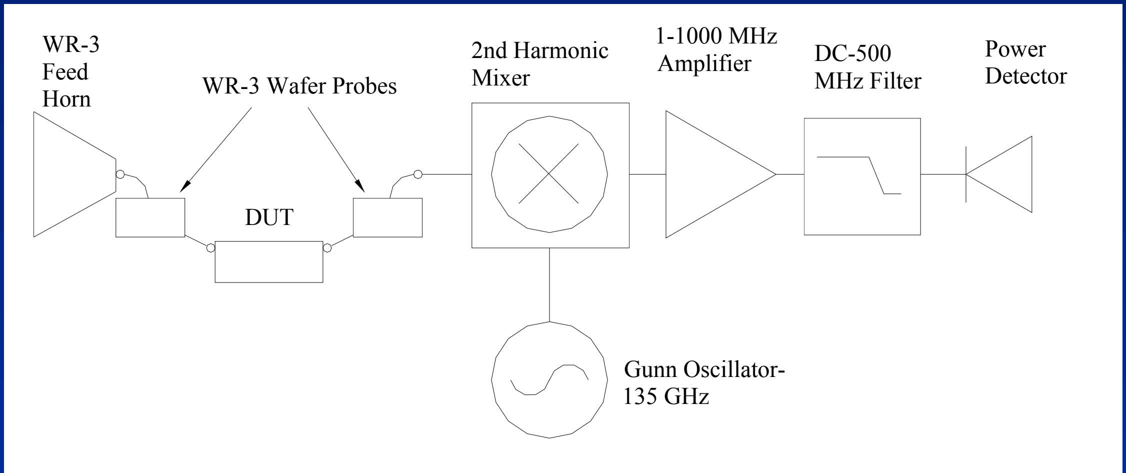


Waveguide Module

MMIC Low Noise Amplifier Module



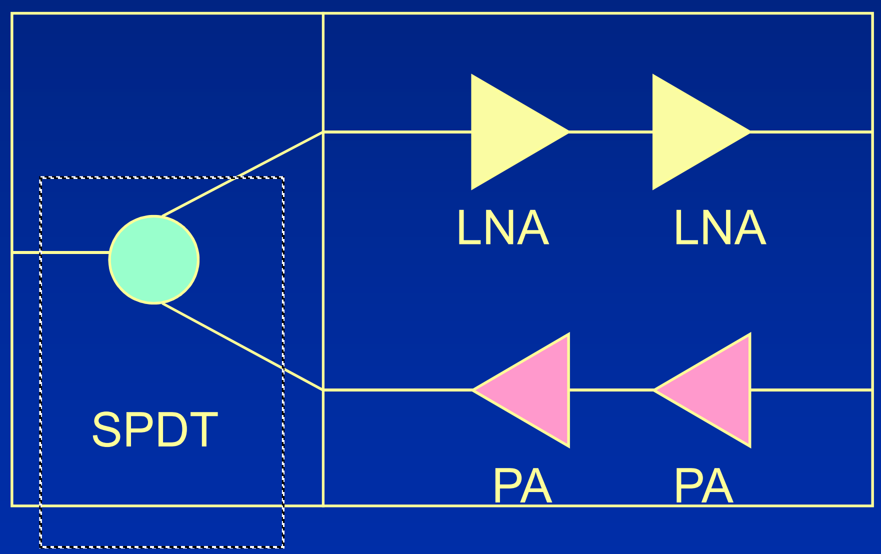
Noise Figure Measurement



Noise figure measured to be 7 dB @ 160 GHz

Maximum noise figure for T/R: 8 dB

Single-Pole-Double-Throw (SPDT) T/R Switch



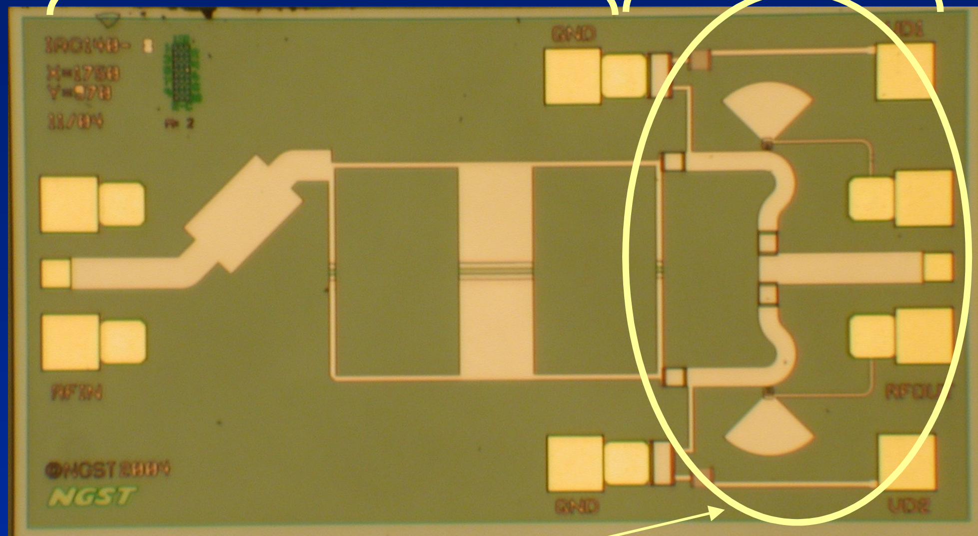
SPDT Switch

- We looked into the viability of a Single-pole-double throw (SPDT) switch, made out of InGaAs PIN diode MMICs for 160 GHz.
- For another program, a 180 degree phase switch for 140 GHz astrophysics polarimeters was developed at JPL and fabricated at NGST. The circuit contained a SPDT component.
- Prior results include Q-band phase switches in this process
- We were able to use this phase switch circuit to a) simulate the effect of the SPDT alone; and b) dice the chip and measure the SPDT portion in a test circuit.

G-Band Phase Switch MMIC

180 Deg Hybrid

SPDT PIN Switch

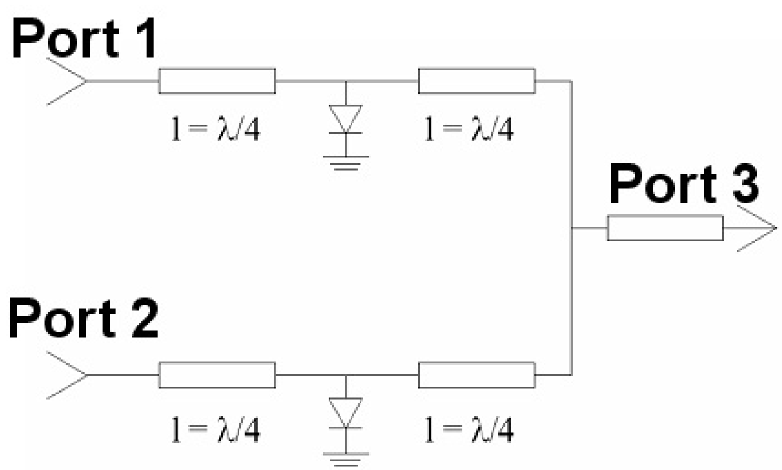


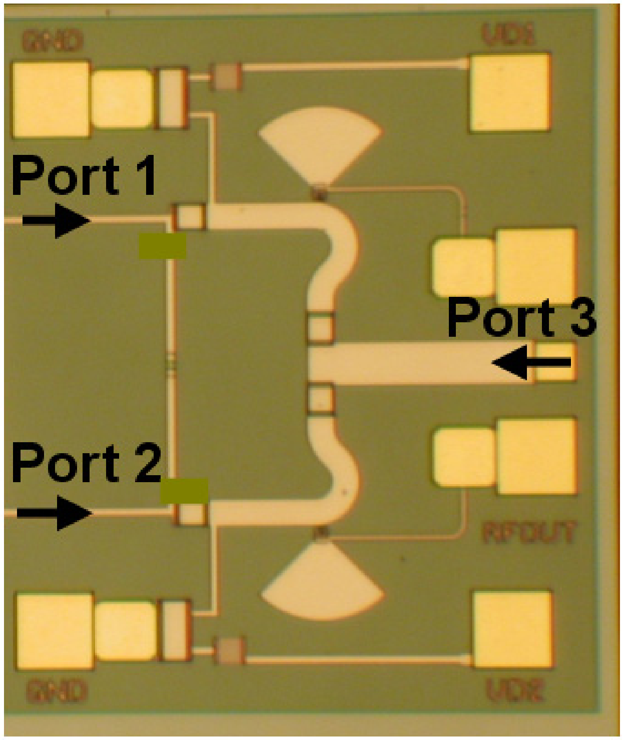
Fabricated in NGST's PIN process

This part of the circuit is effectively a SPDT switch using PIN diodes.

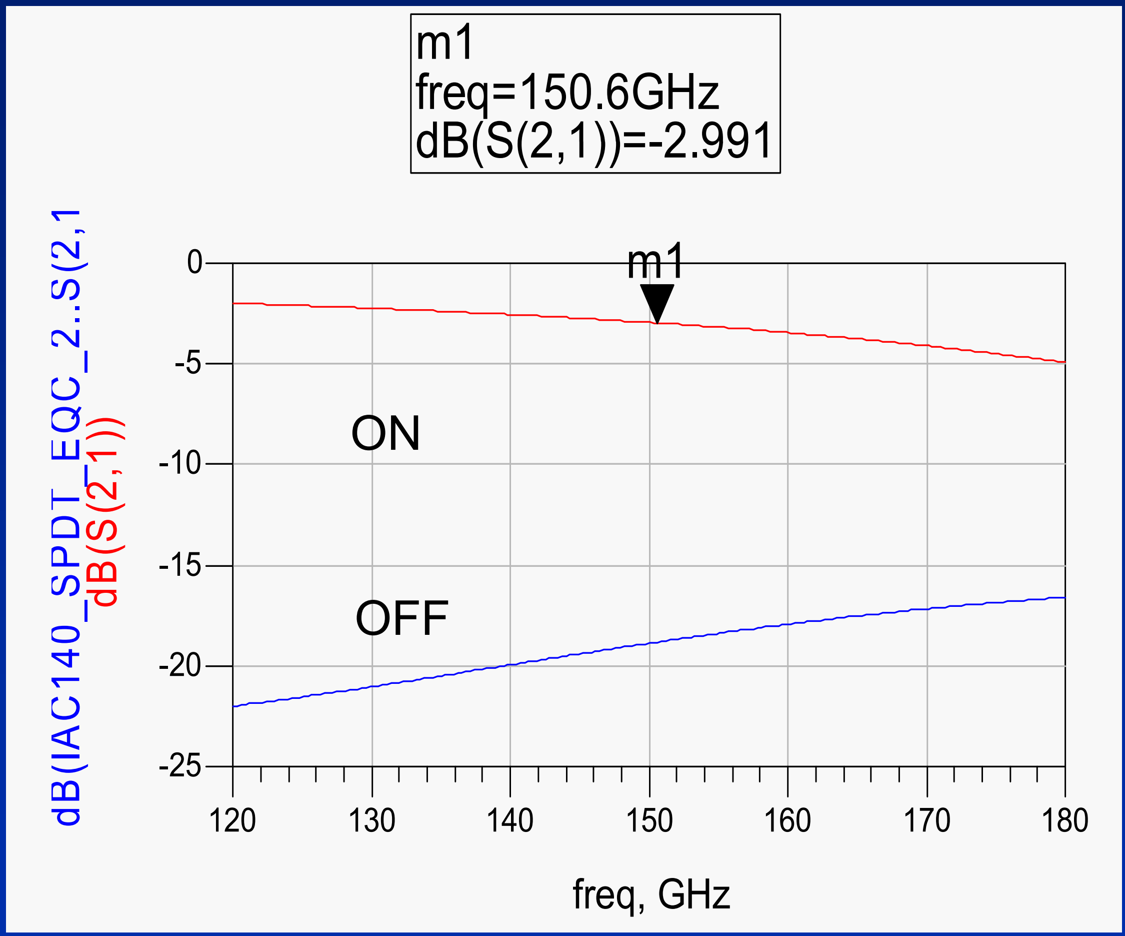
- Insertion Loss of the whole chip including the 180 degree hybrid is 5-6 dB from 140-165 GHz
- The isolation (when both diodes are forward biased) is ~30 dB across most of the WR5 band

Portion of G-Band Phase Switch Circuit

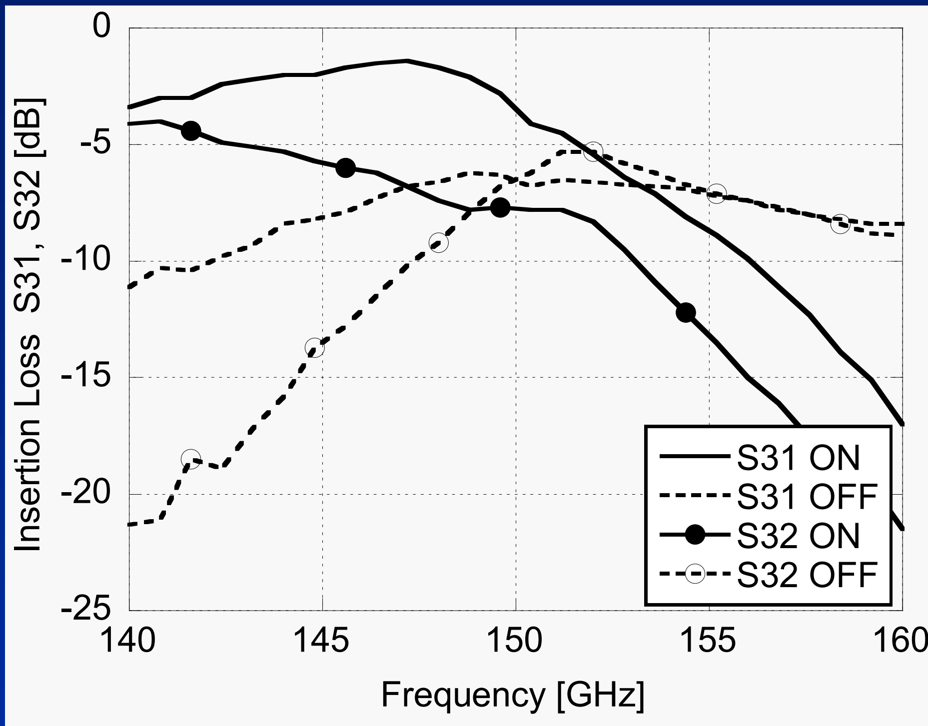




Simulated SPDT portion of the Phase Switch



Measured Insertion Loss, Isolation



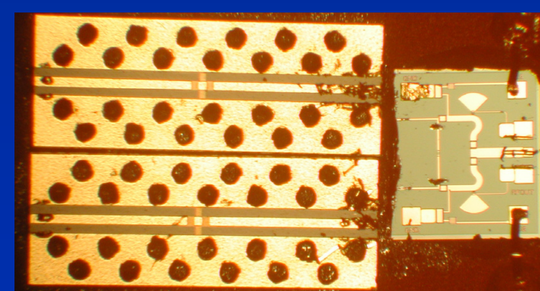
Switching action may be imperfect because:

Circuit was not designed for SPDT but phase switch

We could not break out the SPDT from the MMIC easily

The measurement required the use of wire-bonded attenuators to terminate the third port for 2-port testing.

The low insertion loss on S31 is promising for future work.

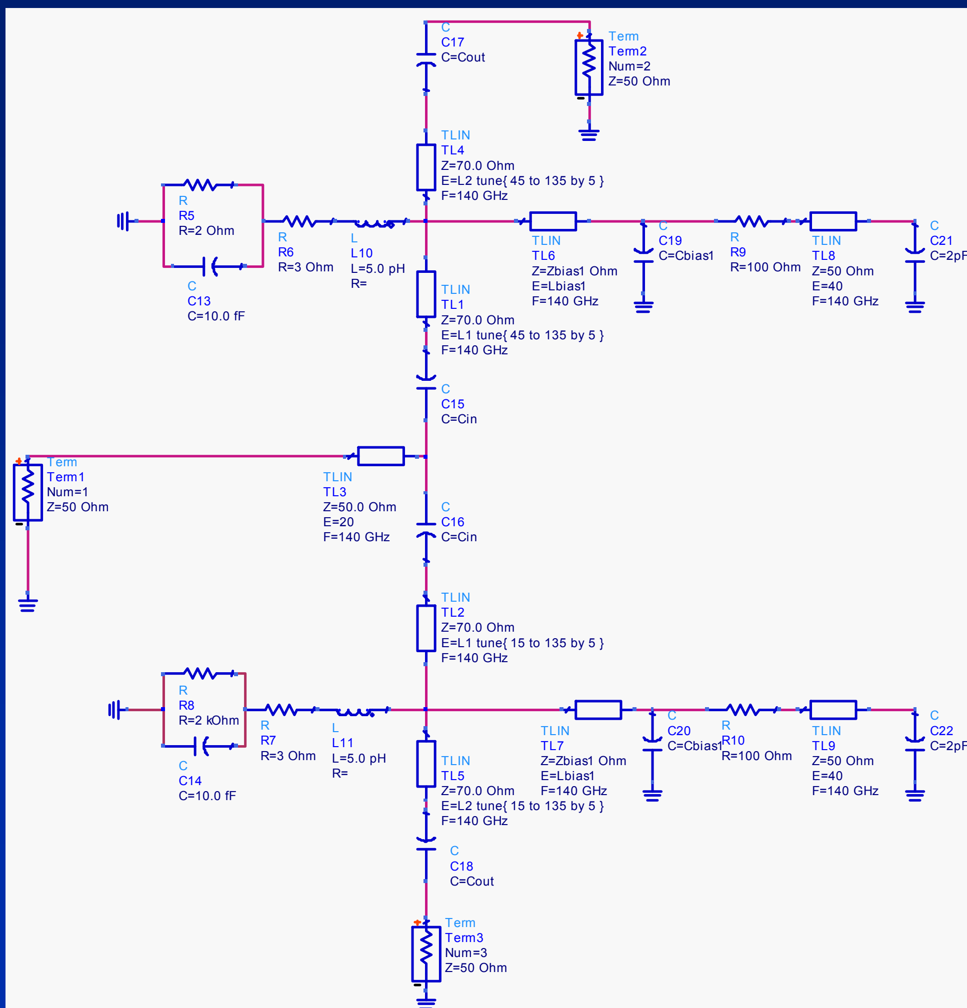


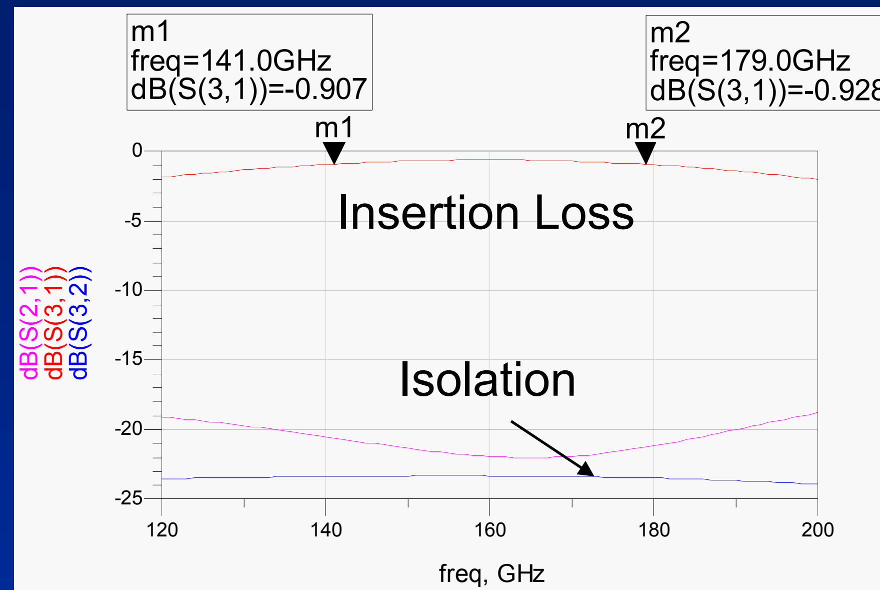
Test Circuit

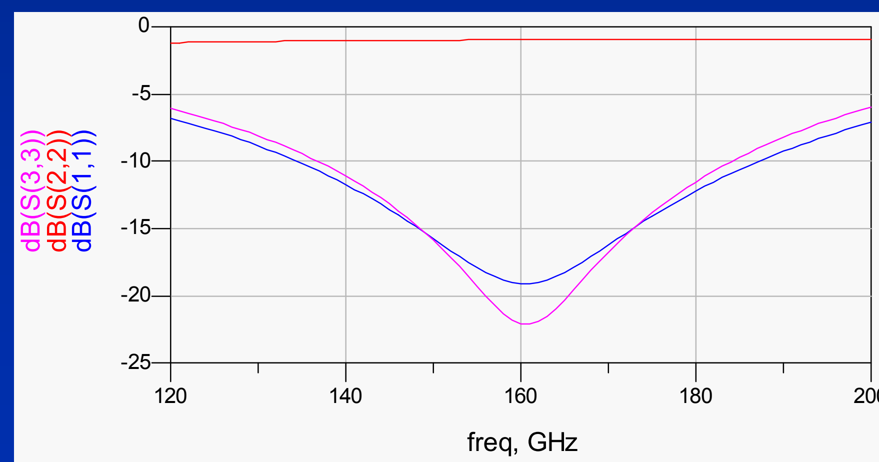
New SPDT Switch Design

- Low-power switch design optimized for SPDT-only characteristics is completed, with estimated >20 dB isolation and ~1 dB insertion loss.
- For layout, CPWG topology appears favorable to microstrip, due to via inductance required for grounding the diode in the microstrip case.
- Layout work is in progress.
- Anticipated PIN diode wafer run will take place in 2007 at NGST.

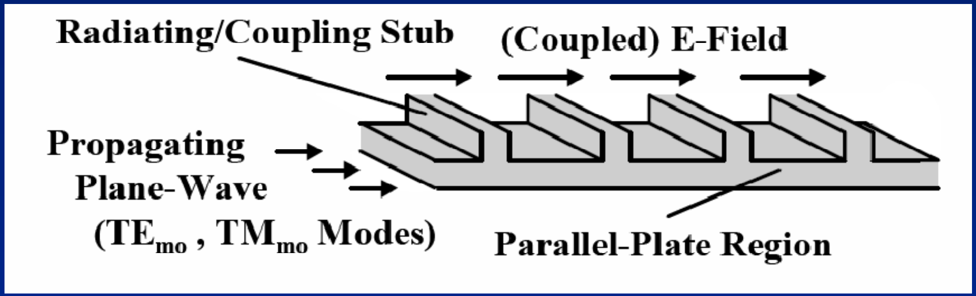
New SPDT Switch Design







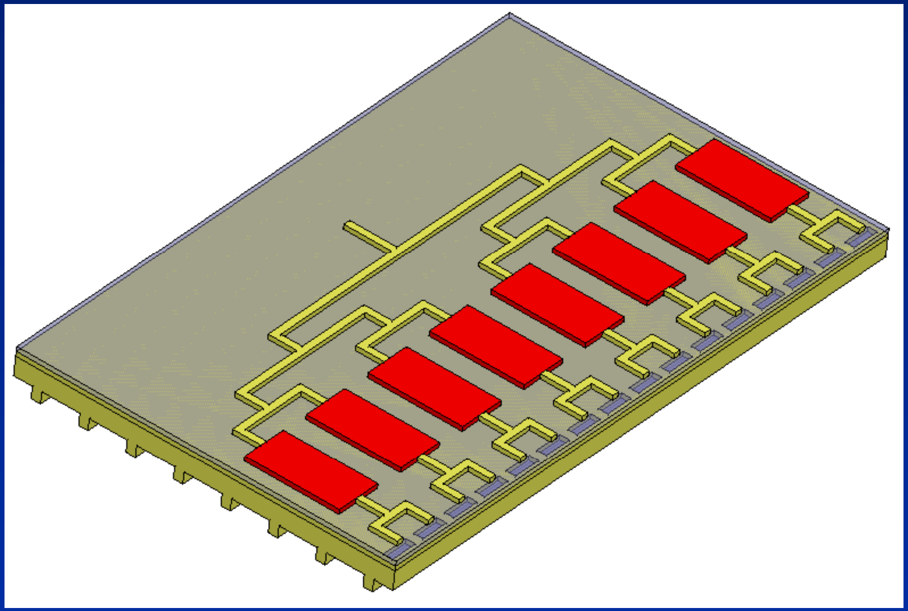
Antenna and Interface

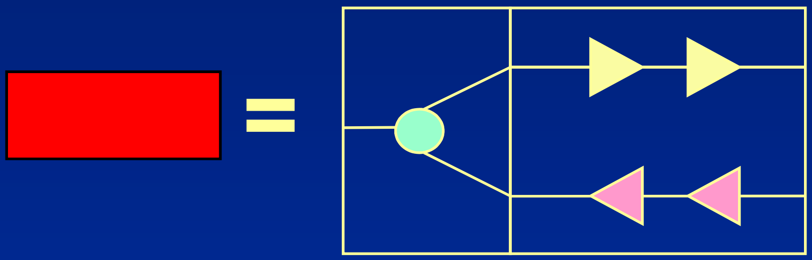


Continuous
Transverse Stub (CTS)
(Henderson & Milroy, 2005)

1. Propagating plane wave enters parallel plate waveguide.
2. Waveguide is made of dielectric such as silicon
3. Transverse Stubs are formed perpendicular to the waveguide
4. Radiation couples to the transverse stubs and is re-radiated transverse to the incident radiation
5. CTS is particularly suited to making compact arrays.

Antenna and Interface





Bottom-view of a CTS antenna, with T/R line array feeding the edge of the CTS input. MMIC PA, LNA, and SPDT switches will be inserted into the chip cavities.

Summary

Transmit:

- We have tested the functional block of the power amp cascade and found it to be stable and capable of 17 mW at 142 GHz.

Receive:

- We have designed a WR5 waveguide LNA block for 140-180 GHz and it is currently in fabrication

Switch:

- A SPDT switch test circuit was assembled & tested from a PIN-diode MMIC.
- The test circuit had 2-3 dB insertion loss from 140-150 GHz on one of the switched inputs.
- We designed a new optimized circuit for an SPDT with 1 dB insertion loss and >20 dB isolation.

Acknowledgments

- NGST and HRL Laboratories, LLC for MMIC fabrication.
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