Design and Validation of RF-MEMS Wide Band Phase Shifters in Harsh Environments

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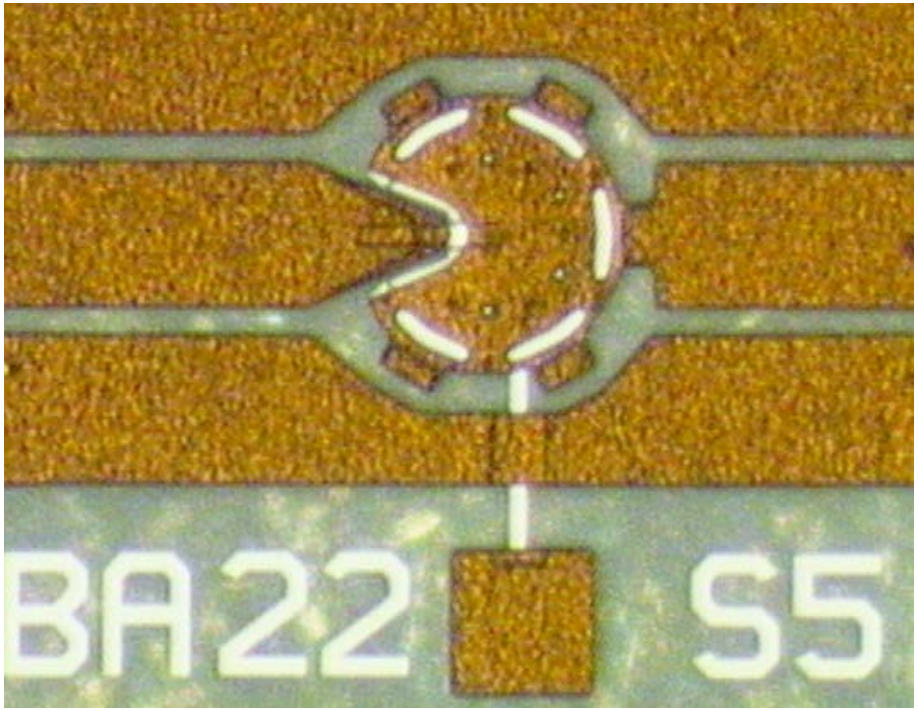
RF-MEMS Developments

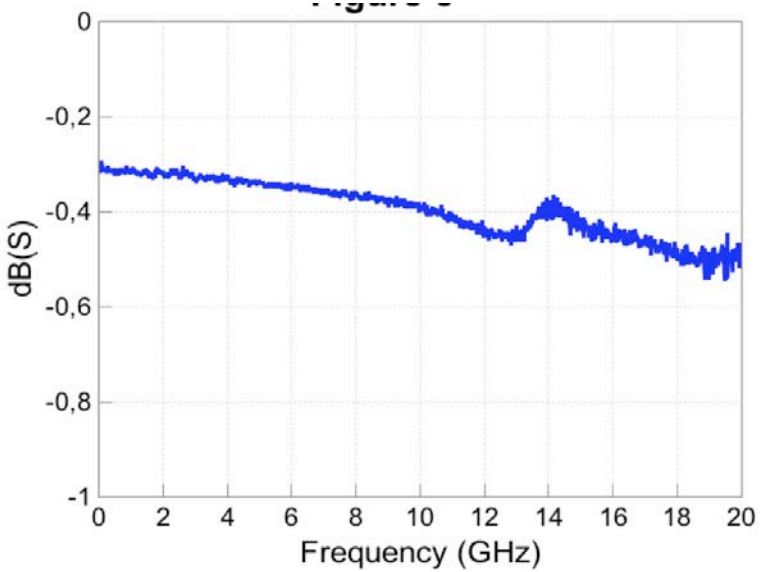
- Phase shifters with RF-MEMS Ohmic switches
  - Low R_{on} – Low C_{off}
  - Control voltage 60 Volts – no power consumption
  - T_{on} T_{off} ~ 4 µsec
  - Reliability > 10^8 cycles – Power handling few Watts
- Fabrication at XLIM Laboratory
- Fabrication and flip-chip assembly up to Ka-Band
  - Filters
  - Phase shifters
- AirMems startup for the commercialization of RF-MEMS

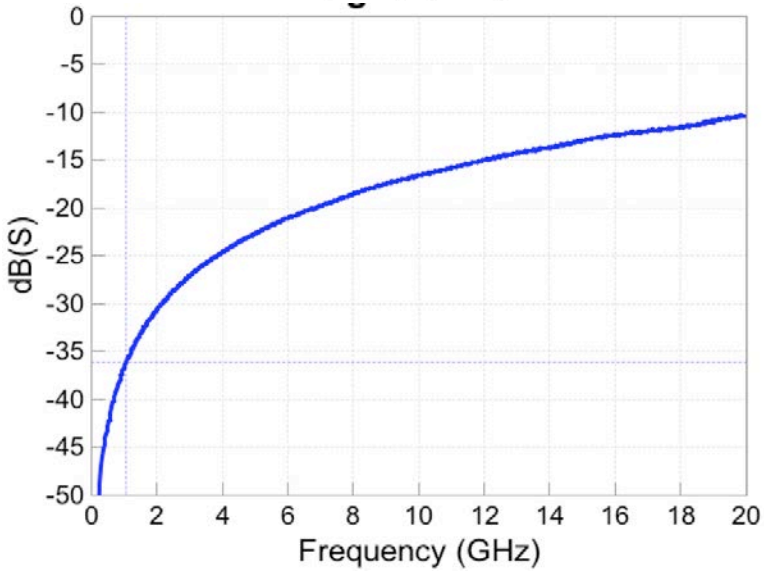
RF-MEMS Context

- Rapidly evolving technology
  - Integration into cell-phones is under way
- Defense applications are emerging
- Advanced experiments for space (MEMO) are under way

XLIM/Airmems RF-MEMS Switch

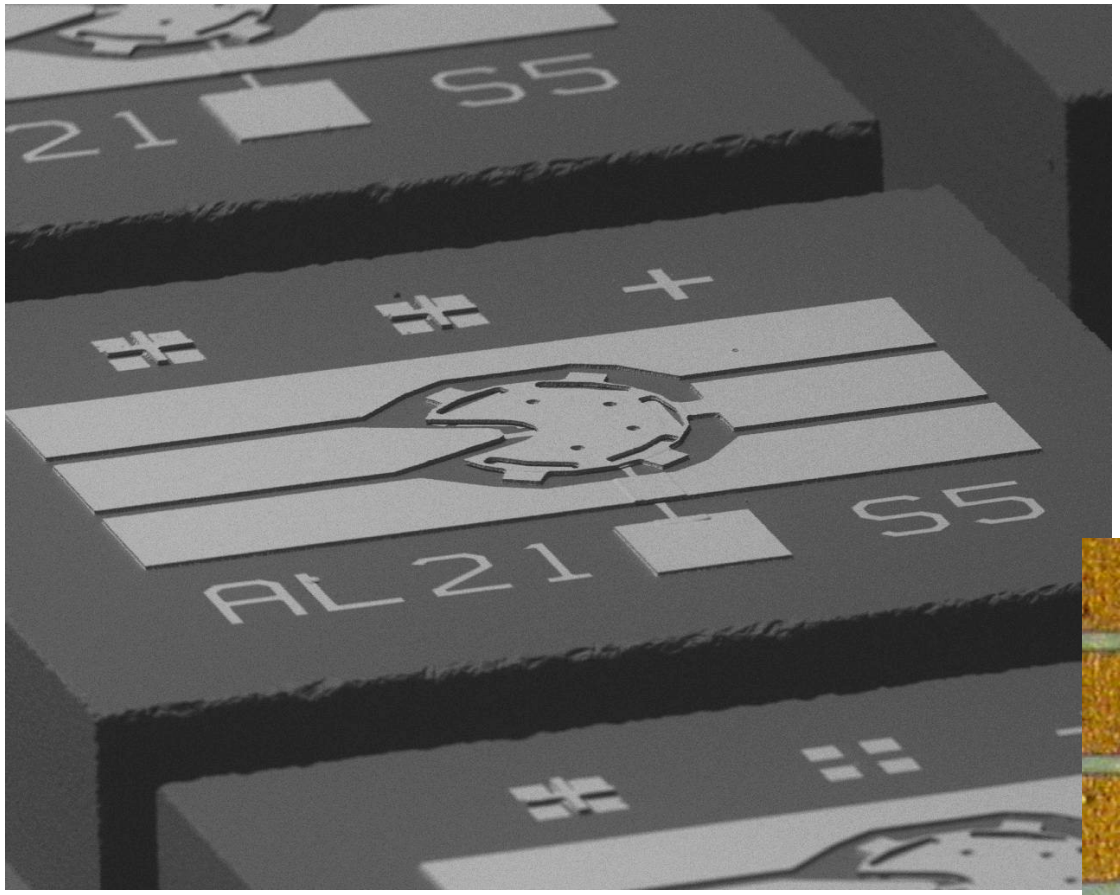


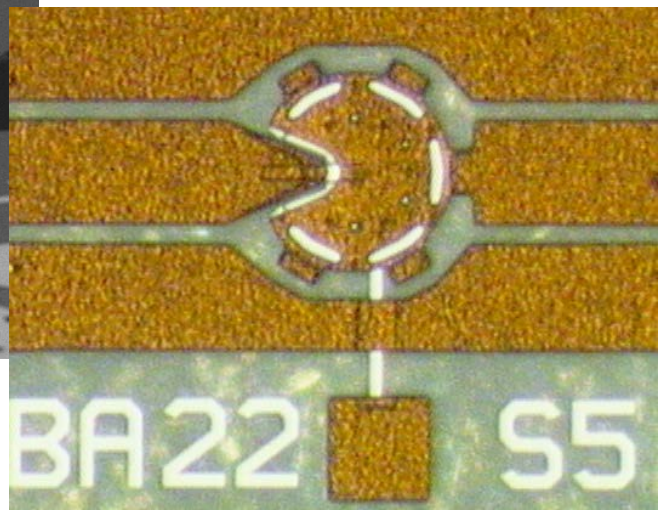




- Large contact force
- Low sensitivity to residual stress
- Temperature stable
- No dielectrics (Air gap switch)

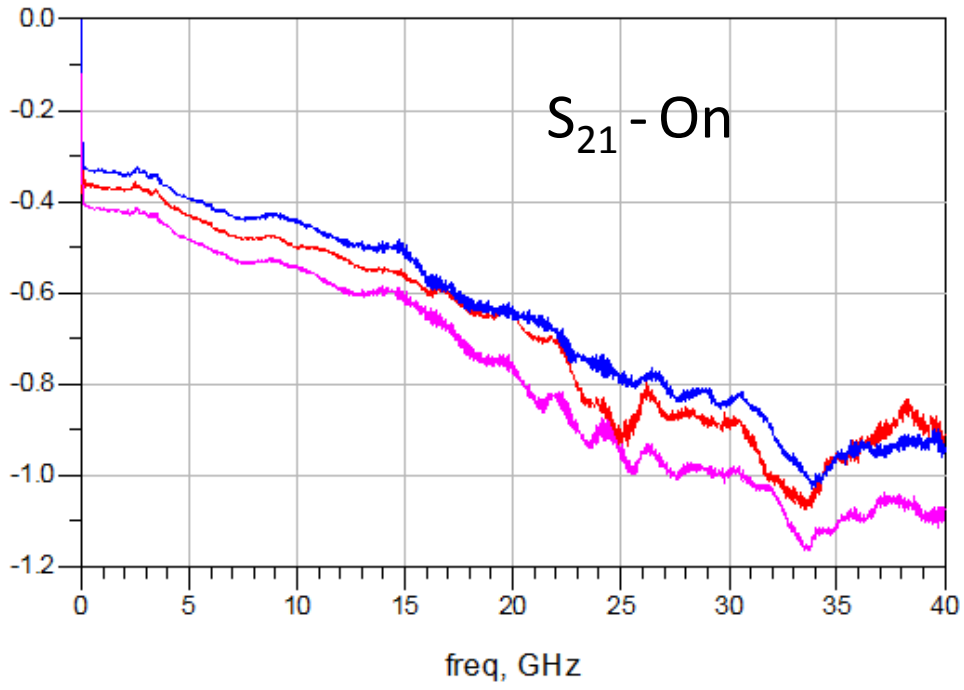
SEM View of XLIM Relay

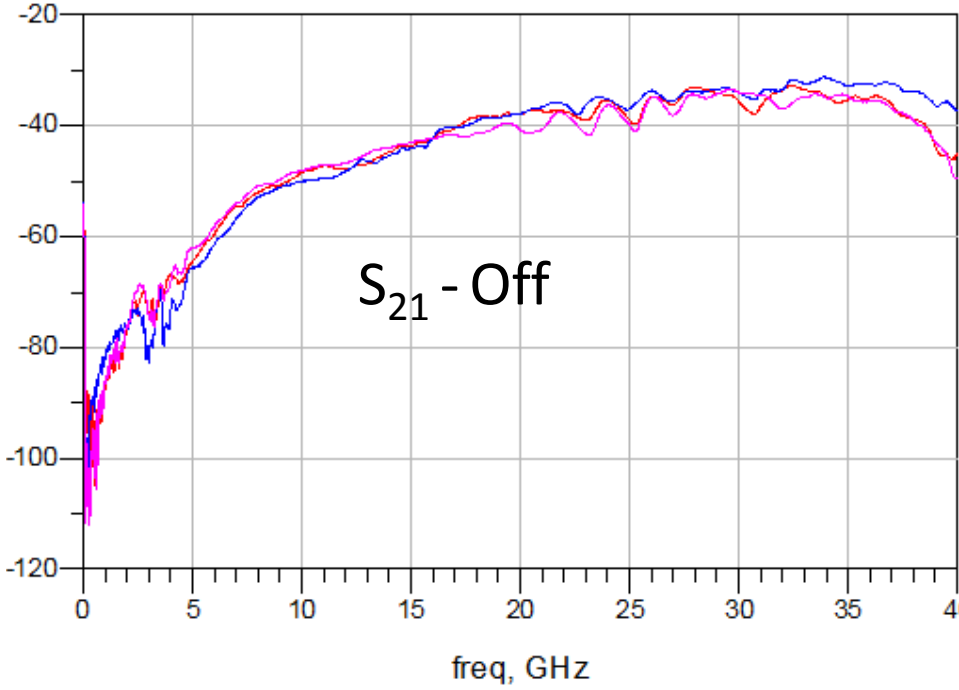




RF-MEMS Switch XLIM/ Airmems

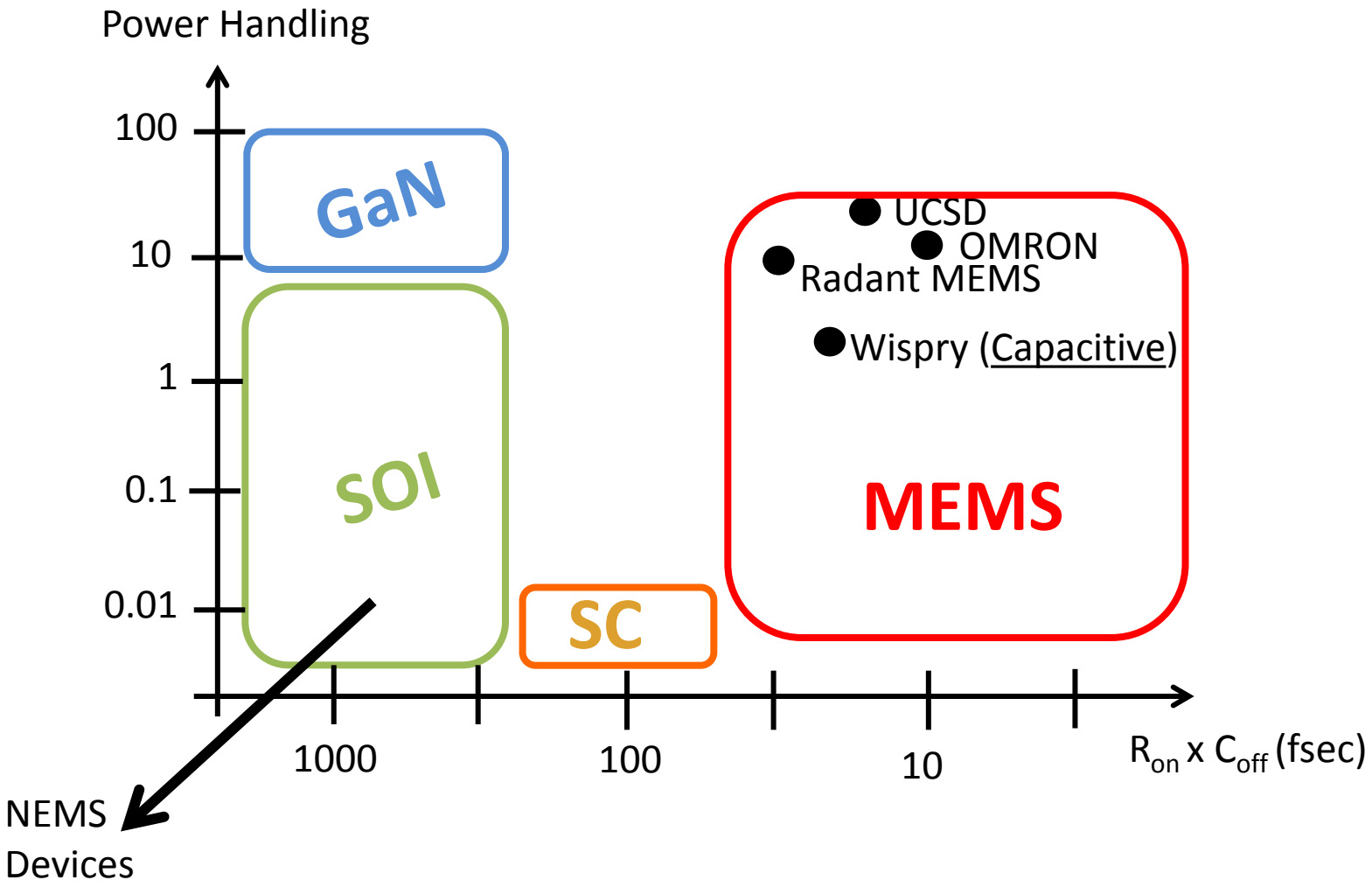
- Series-Shunt arrangement





@ 10 GHz: 0.5 dB loss - > 50 dB isolation

RF-MEMS-RF and SC



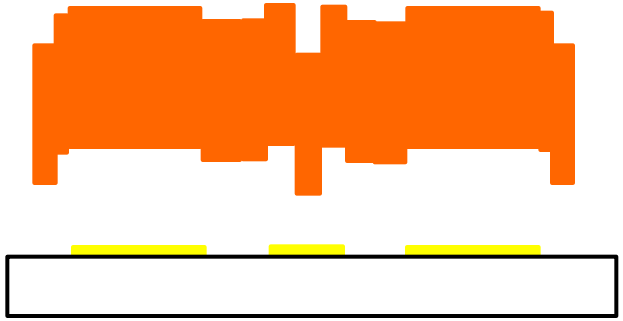
Process

1 - Métal 1

2 – Sacri 1 (dimple)

3 – Sacri 2

4 – Metal2



5 – Release

Reliability - Physics of Failure

- Dielectric Charging: Charge retention inside the dielectric layers of the actuator
- Actuator design: crucial in Ohmic RF-MEMS switches
- Contact metallurgy
- Creep: Thin film metals suffer from mechanical creep. This is causing actuation voltage shifting.

Space Vehicle Harsh Environment

Parameters :

-Bandwidth : 2.0 -3.0 GHz;
- SWR <1.5 on each input/output;
- Insertion loss : < 1dB;
- Power handling : 5 W;
- 4 states (0°,90°,180°, 270°) +/-2°.

The climatic environment :

-Temperature : -10°C to +70°C
-Hygrometry : 50% to 100%

The mechanical environment :

-Pyrotechnical shock : until Z1
-Sinusoidal vibration; - acceleration (until 100G)
-Overpressure (5 bar) or vacuum (10-5 bar);

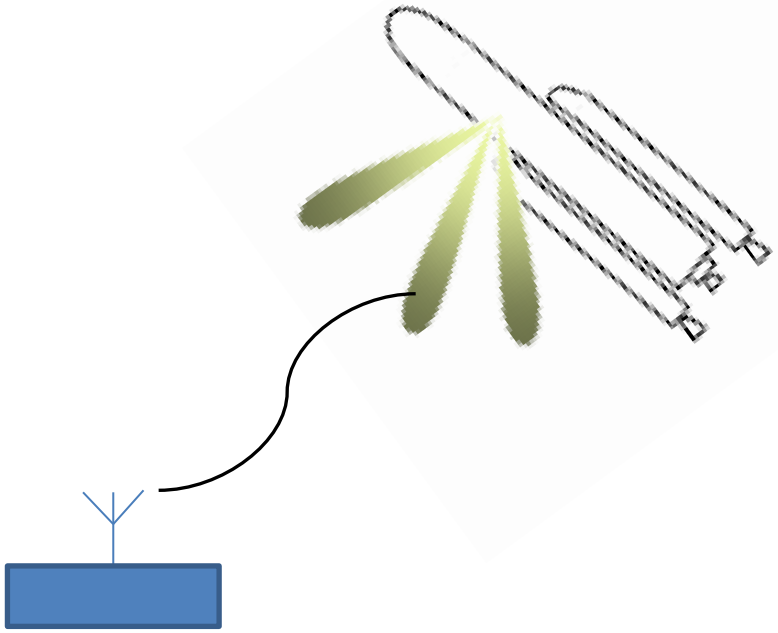
Electromagnetic environment :

-Lightning;
-Electrostatic discharge;
-Radio radar environment;
-Radiated and conducted susceptibility;

Objectives

- **Integrating electronically steerable antennas on launchers :**
  - Improved link budget
  - Decrease in power
  - Reduced volume embedded
- **Telemetry Applications :**

- Knowledge of the internal behavior of the launcher by ground transmission functional parameters of the main components of the launcher and flight events.

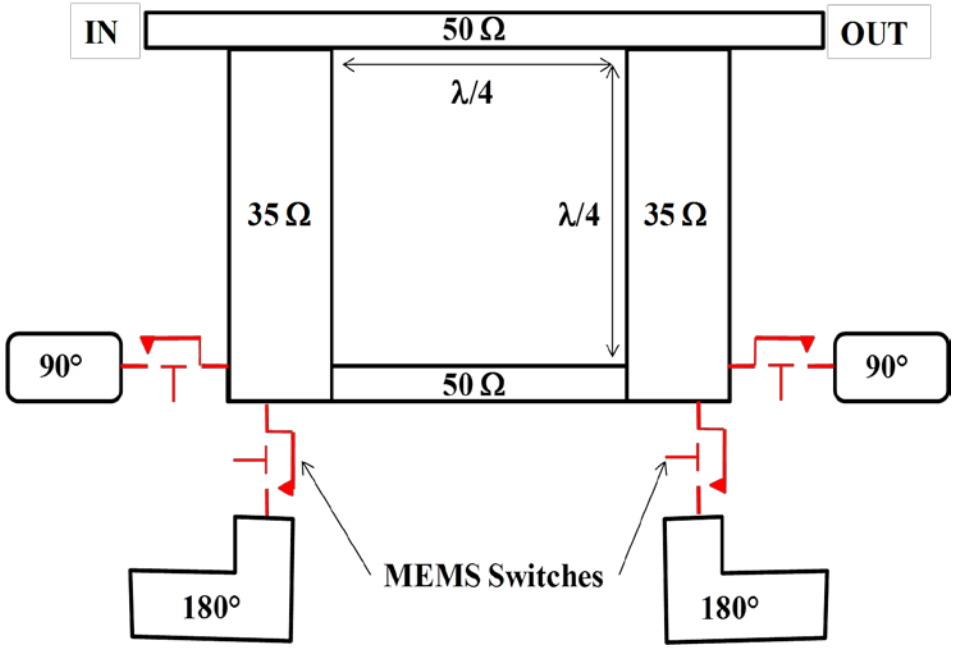


2.2 GHz Phase Shifters

- Hybrid Branch-line couplers have been chosen:
  - Low loss
  - Easy integration
- Fabrication is conducted on Alumina, with hybrid flip-chip integration of MEMS switches

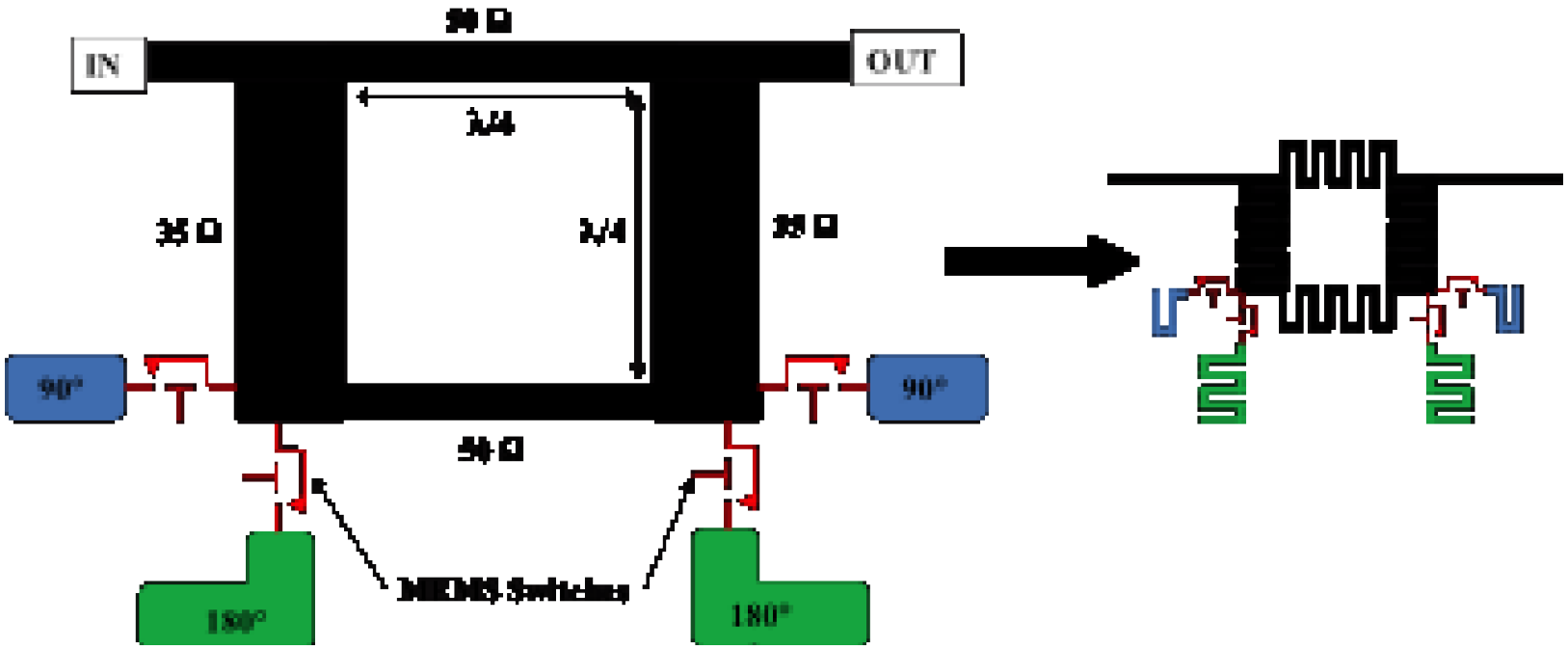
2.2 GHz Phase Shifters

- Operation – balanced design



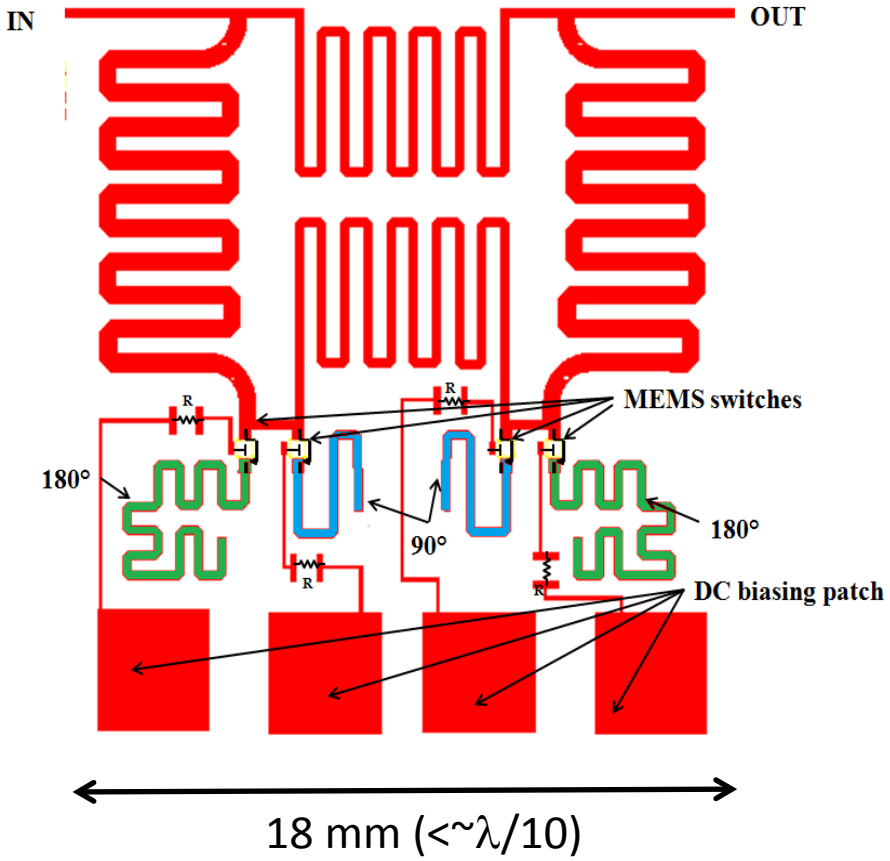
2.2 GHz Phase Shifters

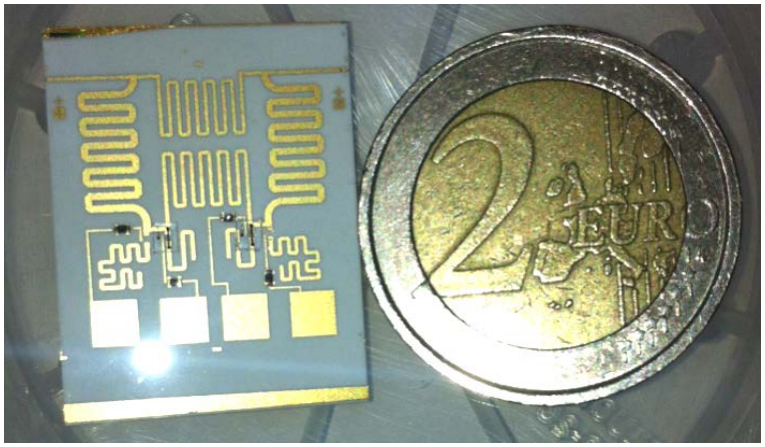
- Operation and Meandered design

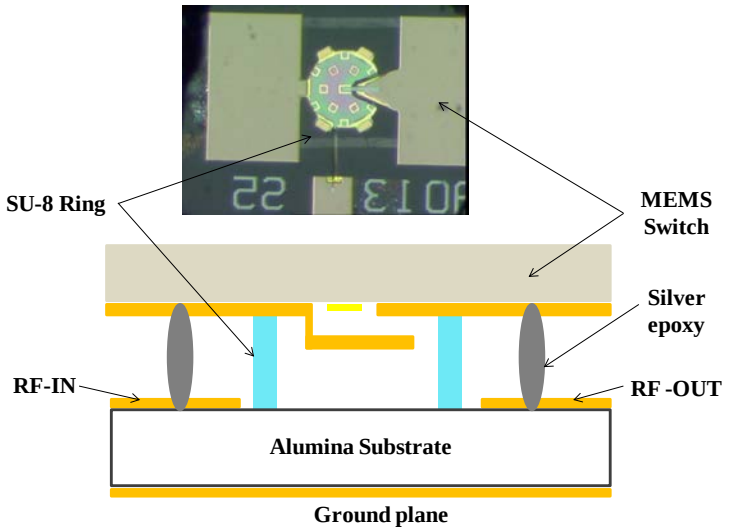


2.2 GHz Phase Shifter

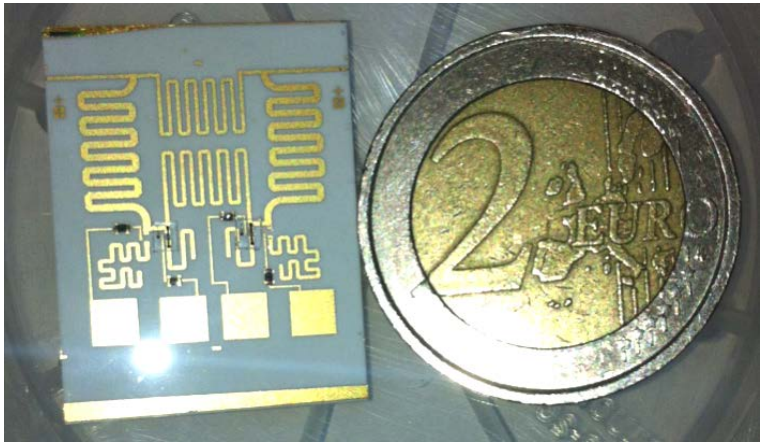
- Final Layout

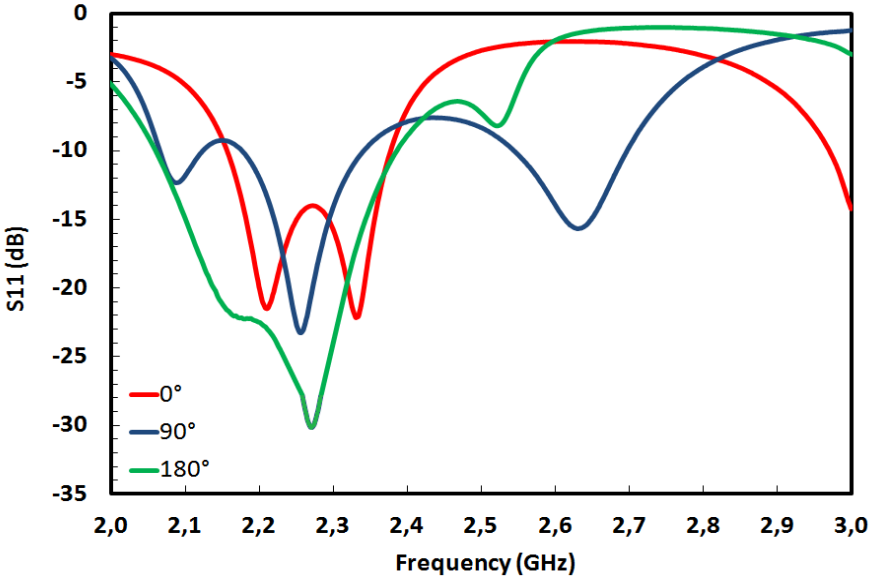


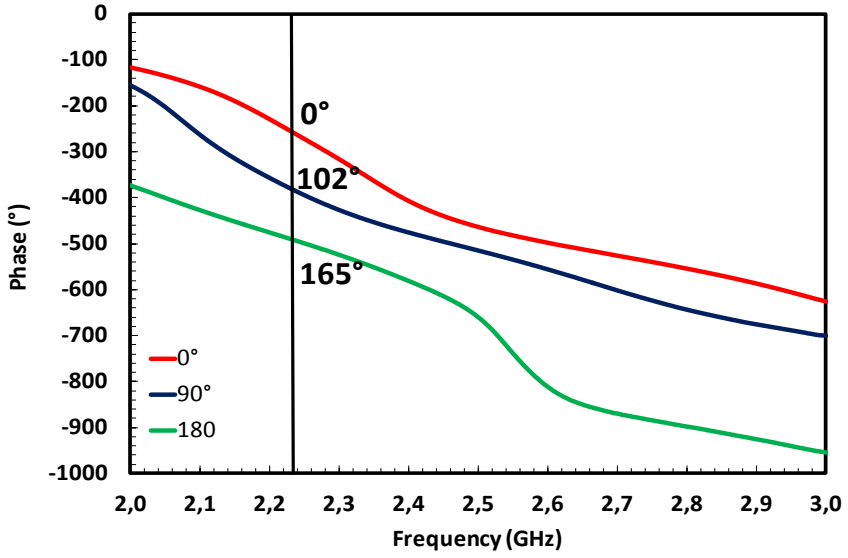


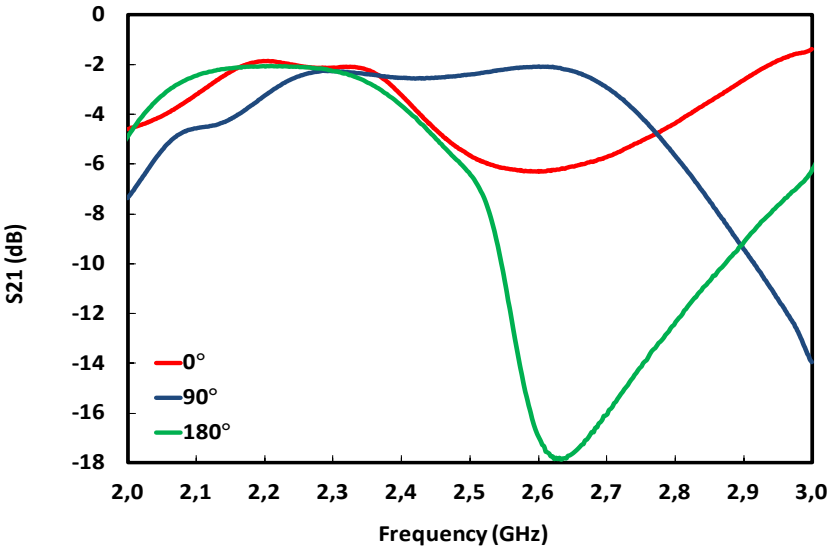


2.2 GHz Phase Shifter - Measurements

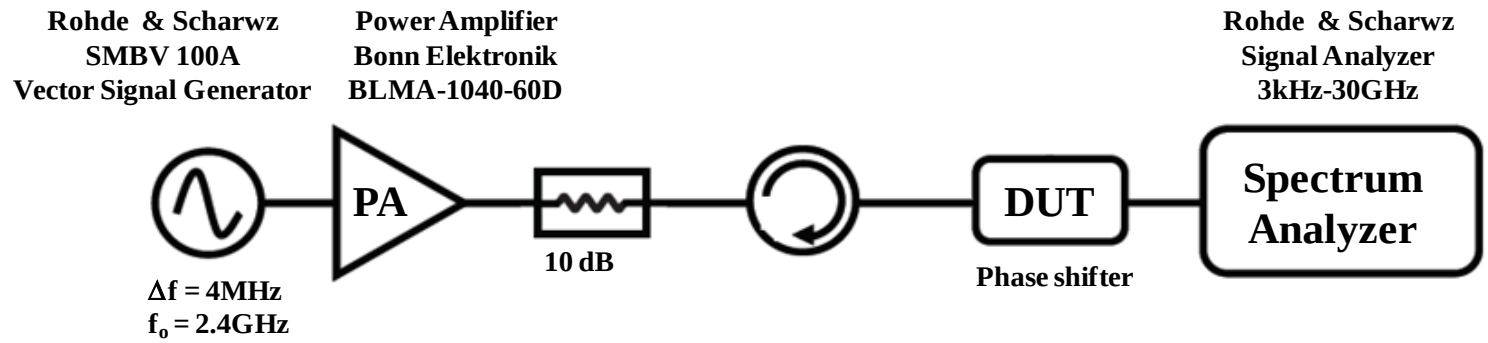


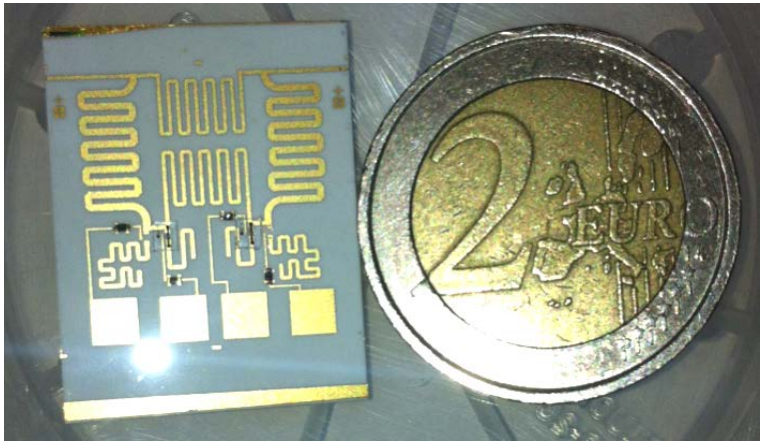


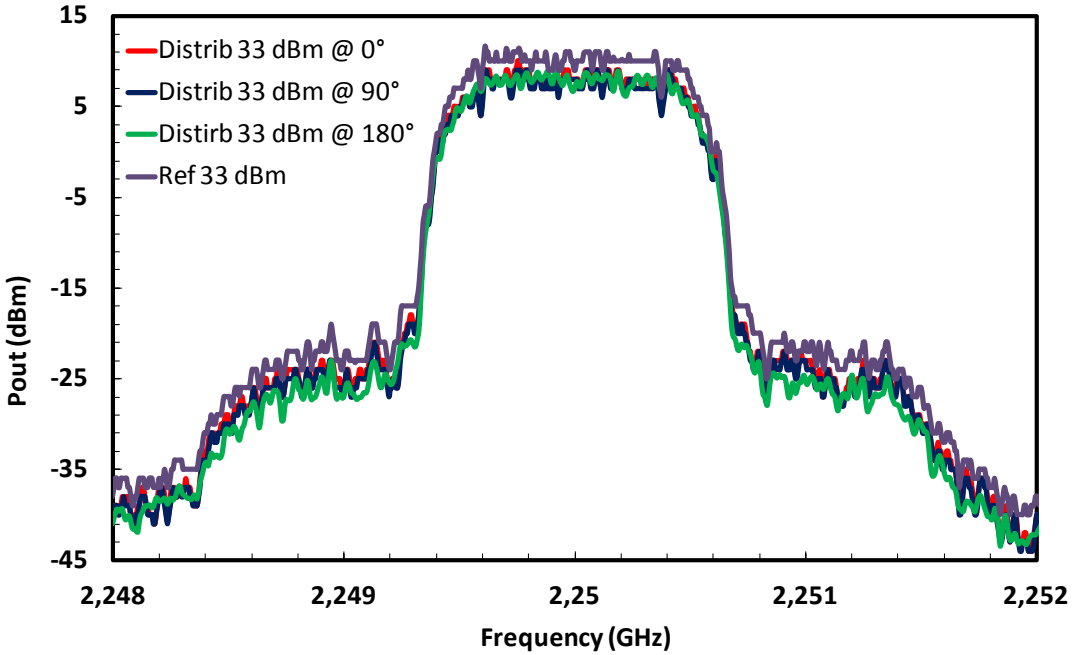




2.2 GHz Phase Shifter Power Handling

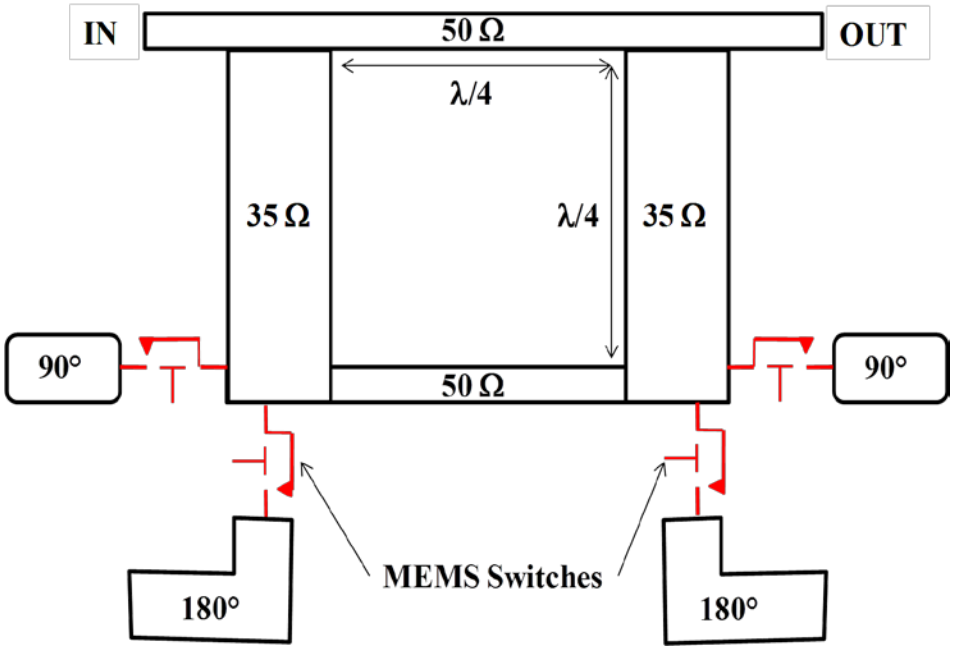


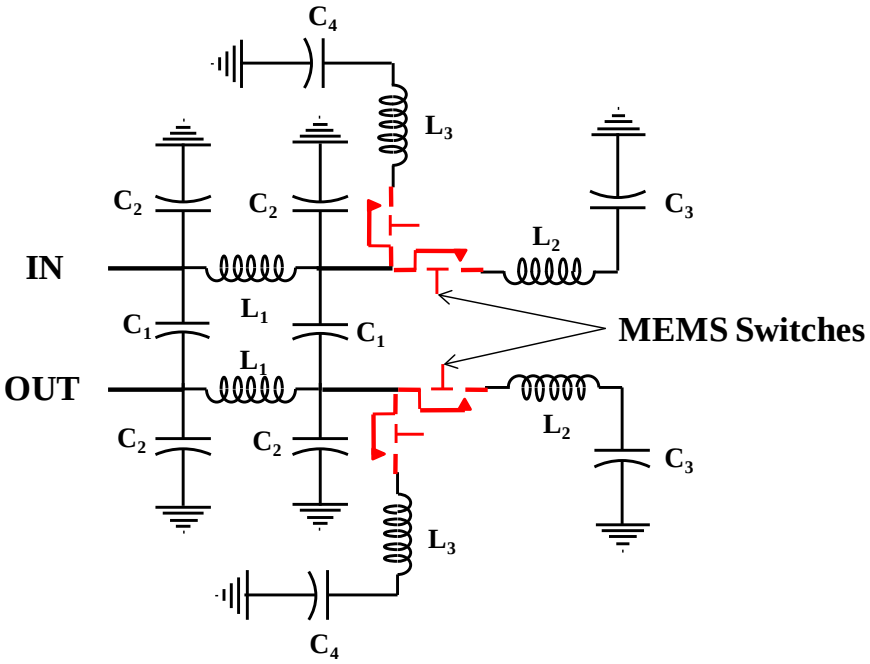




Lumped-Element Version

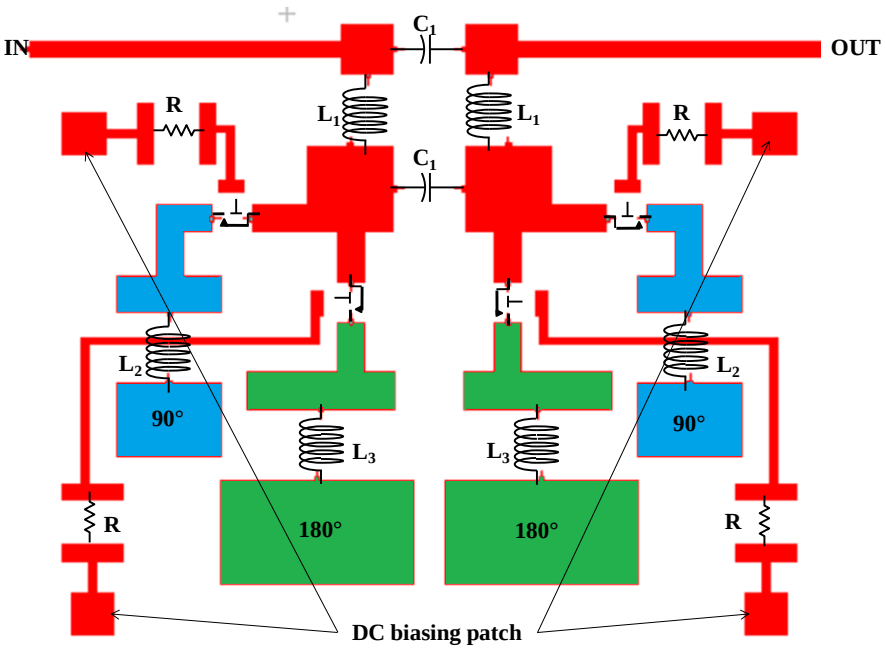
- Compact design



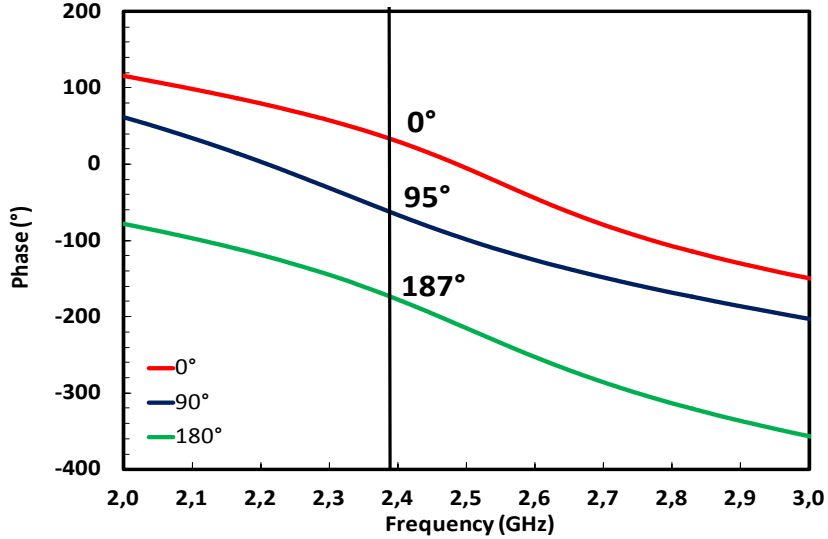


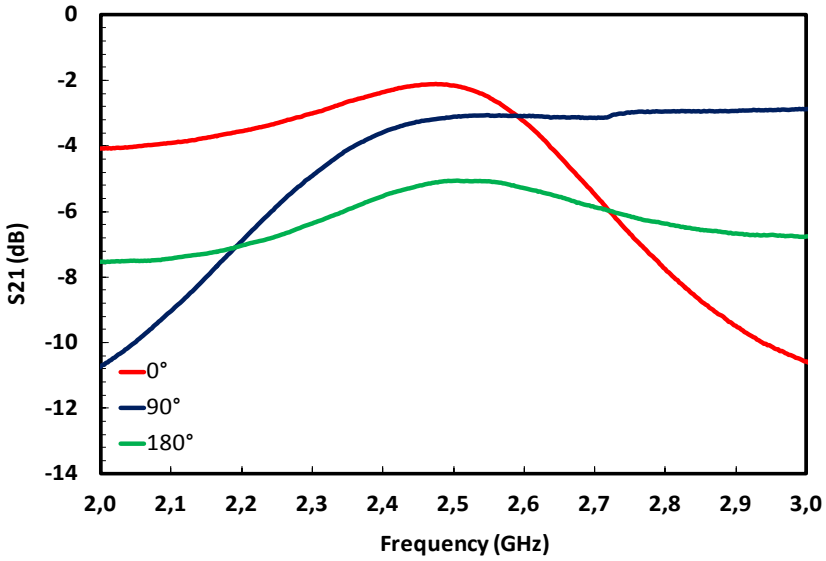
Lumped Element Version

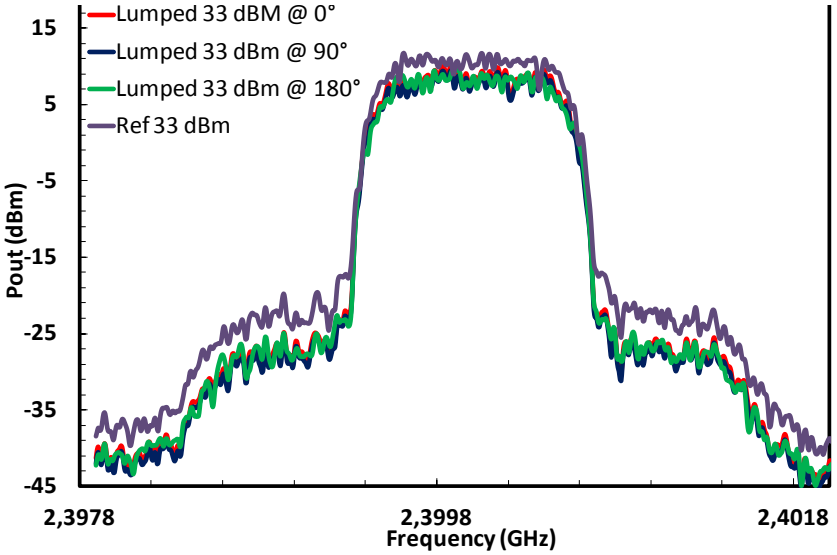
- Final Layout

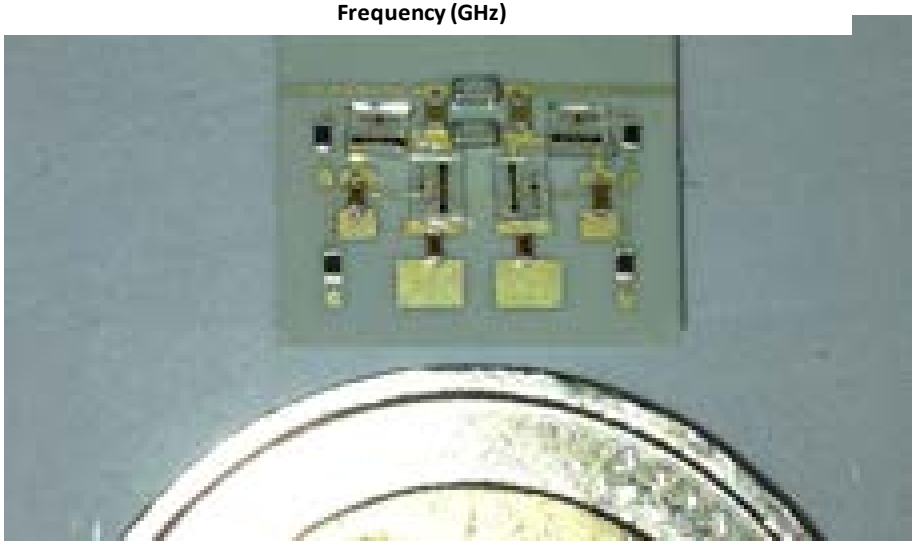


2.2 GHZ Phase Shifters Lumped-Element Version

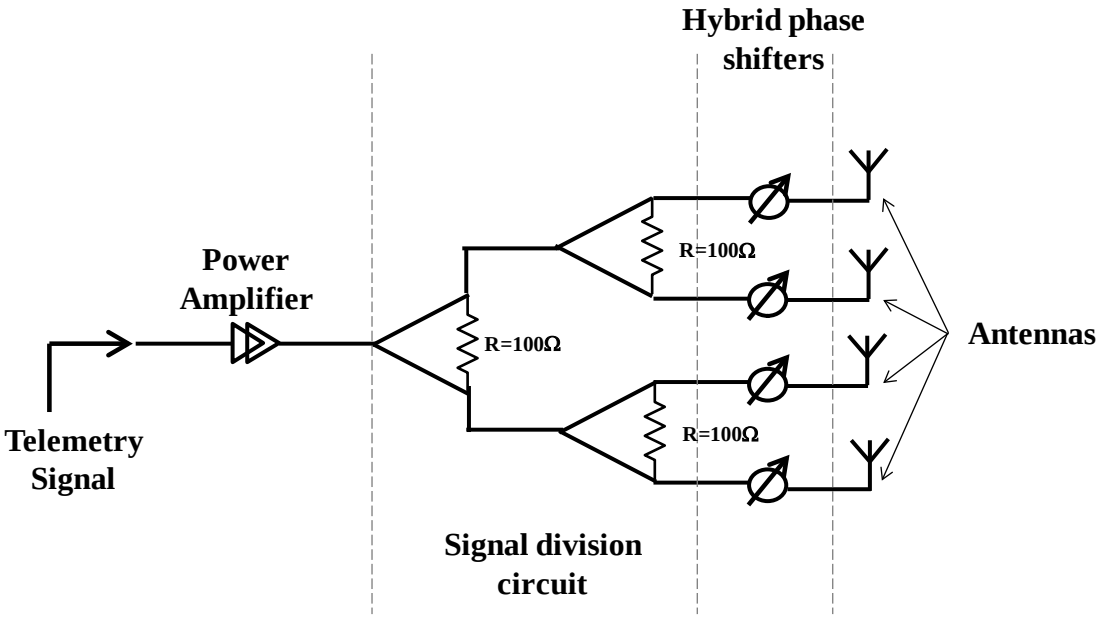


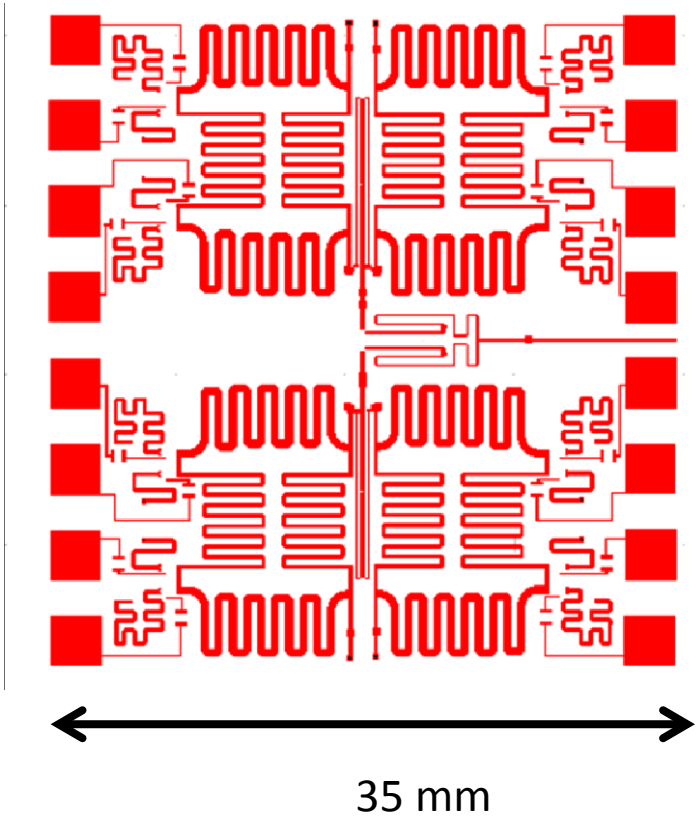






Work in Progress - Integrated Chip





Conclusions

- RF-MEMS is an enabling technology for Low-loss and high linearity RF and microwave components
- Main applications:
  - Reconfigurable components at large (tuners-filters-antennas)
  - High power phase shifters
- Presented results:
  - High linearity (>33dBm) low loss (<2 dB) 2.2 GHz phase shifters
  - Flip chip assembly of RF-MEMS switches