CMOS System on Chip for Compact instruments

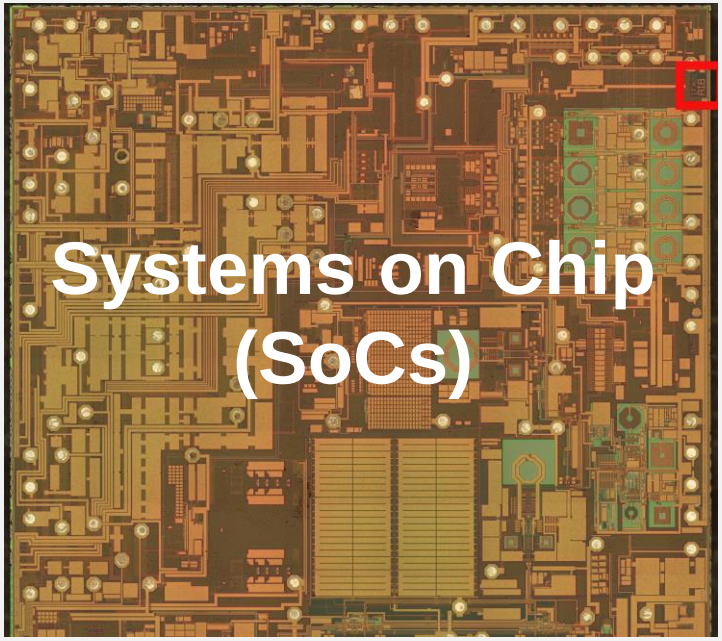
Adrian Tang

Jet Propulsion Laboratory
California Institute of Technology

UCLA University of California, Los Angeles

CMOS SoCs for Instrument Payloads

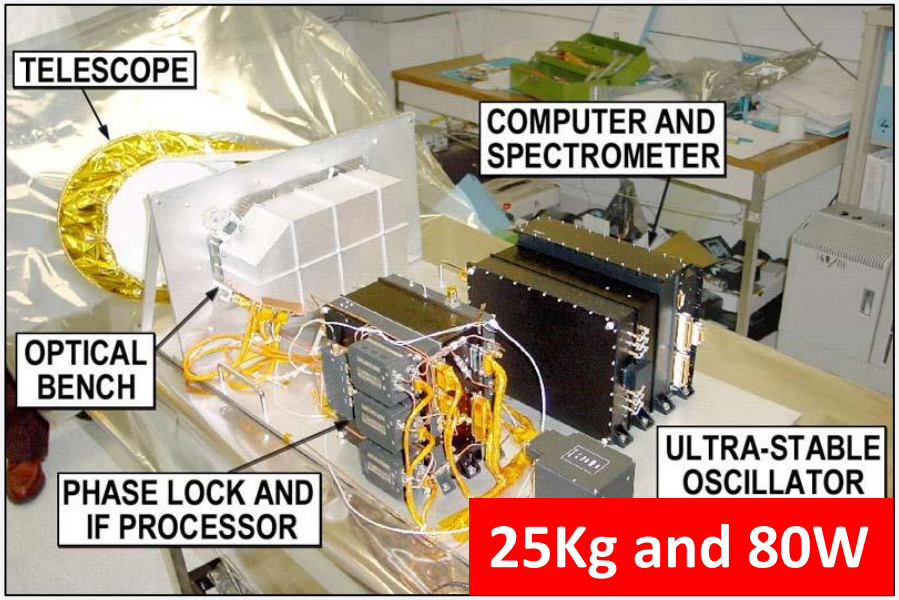
- The incredible integration ability of CMOS SoC technology is what enables modern electronics technology through reduction of system size/power.
- The ability to integrate 1000s of functions and sub-systems (analog, digital, mixed-sig, RF) onto a single-chip is what drives these industries.



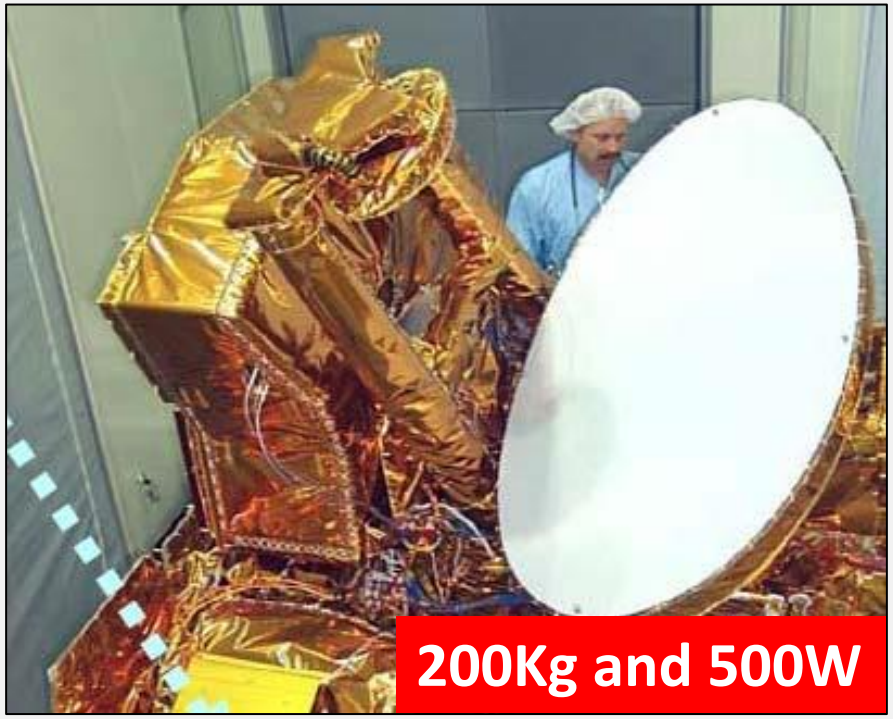
CMOS SoC Radiometers & Spectrometers

Recently Flown Microwave Spectrometers

MIRO (Rosetta)



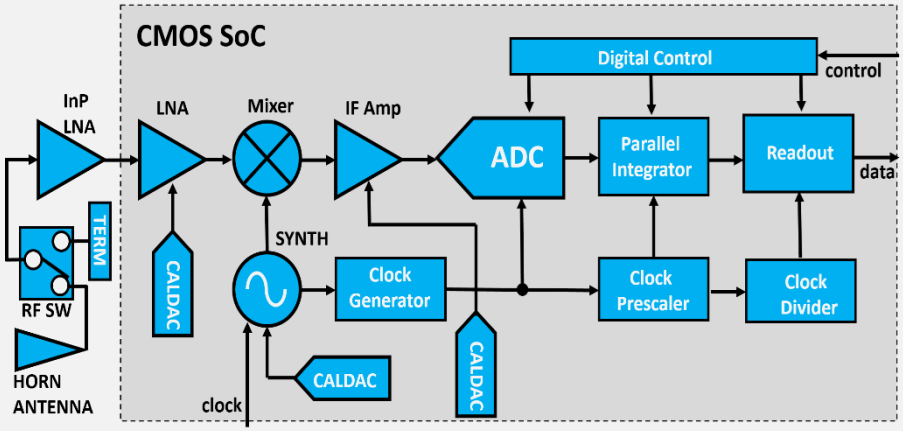
MLS (Aura)

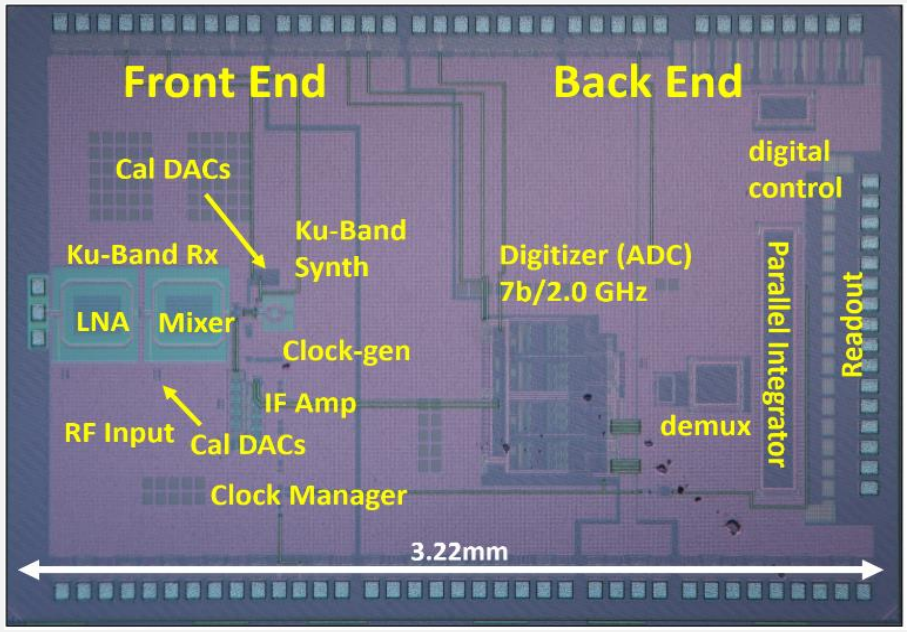


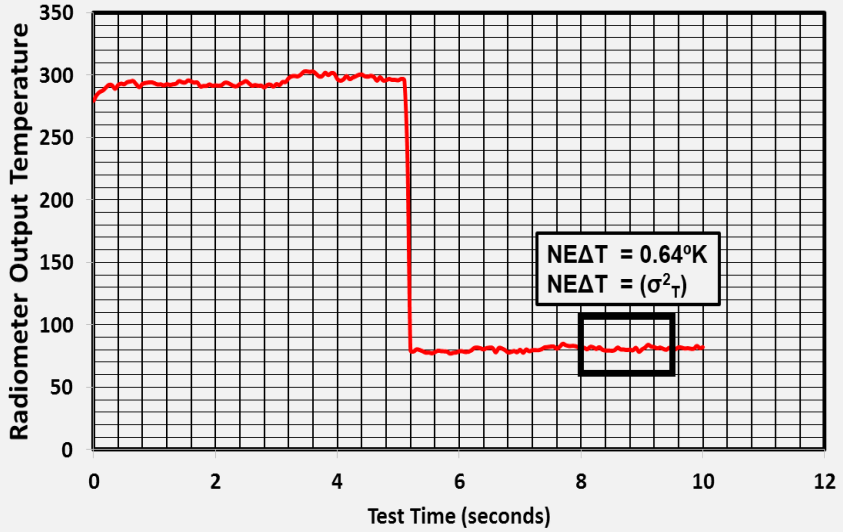
- Microwave wavelength spectrometer instruments are generally pretty payload intensive and have high power consumption but could potentially do a lot of science from compact platforms like cubesats.

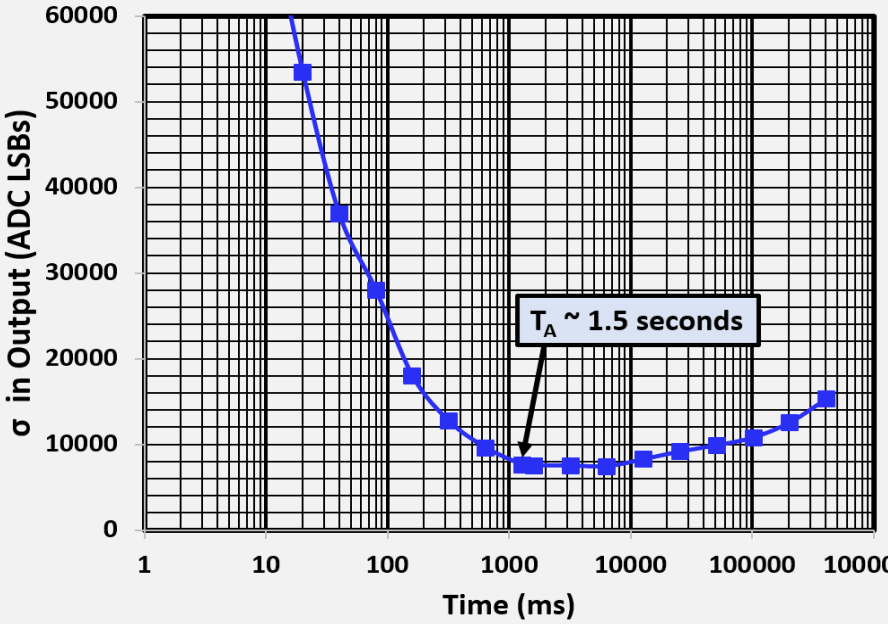
Ku Band CMOS Dicke Radiometer

- First attempt to just implement a radiometer on a CMOS SoC chip.

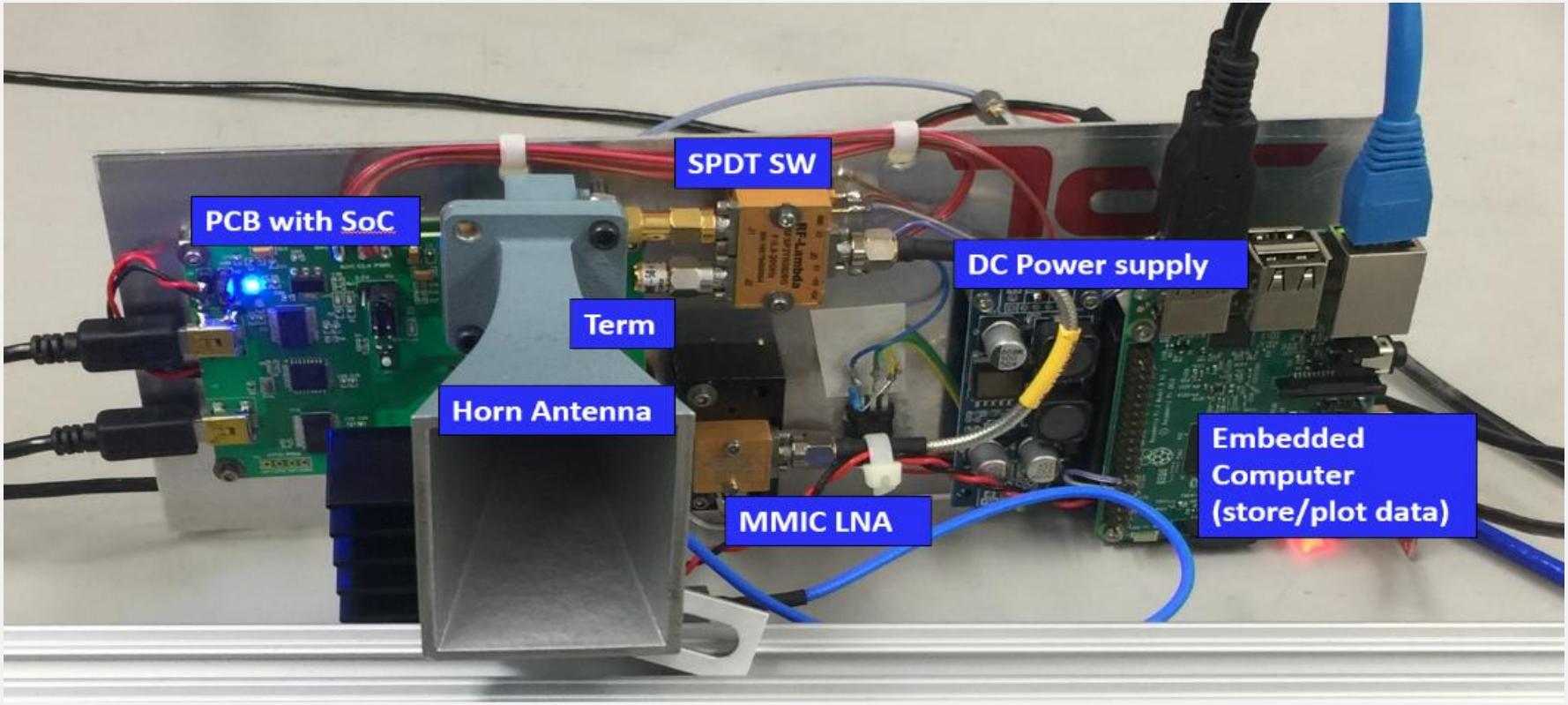






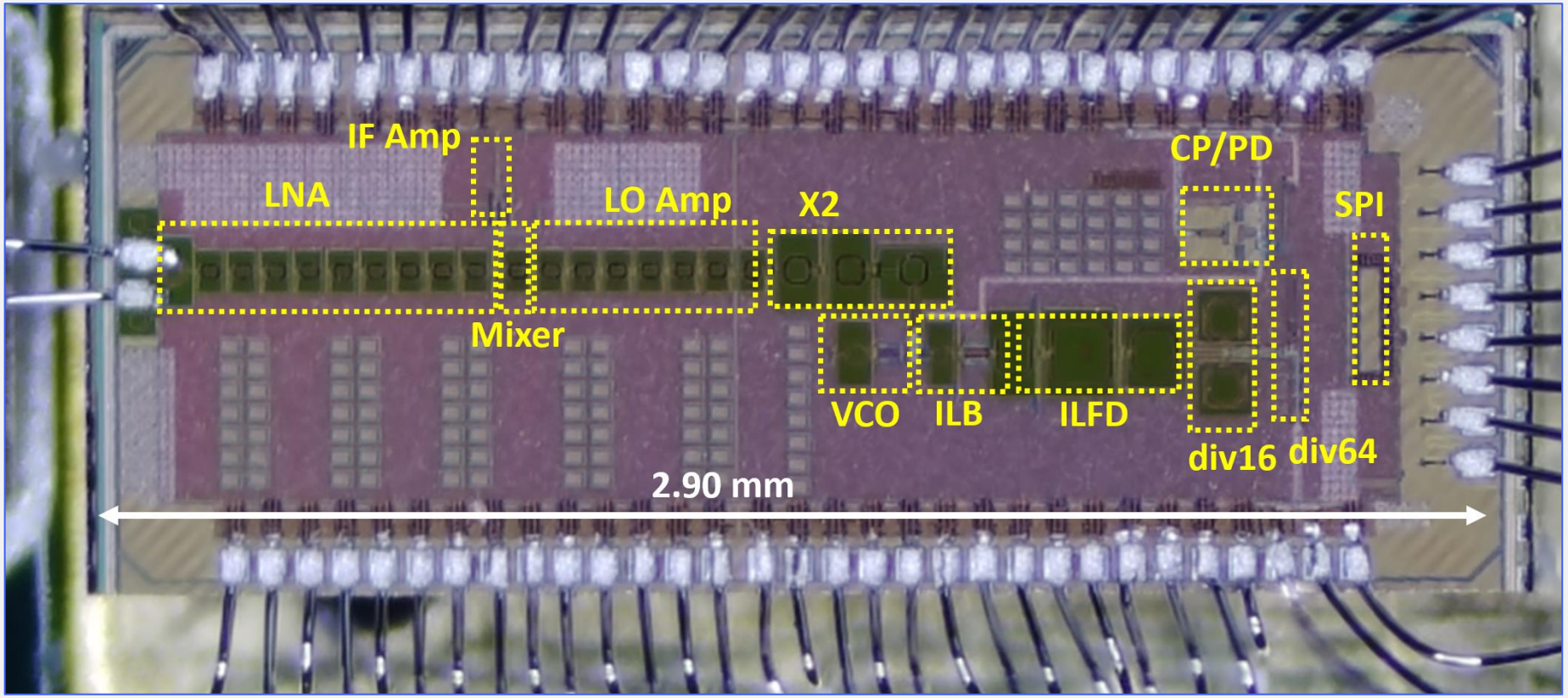


Ku Band CMOS Dicke Radiometer



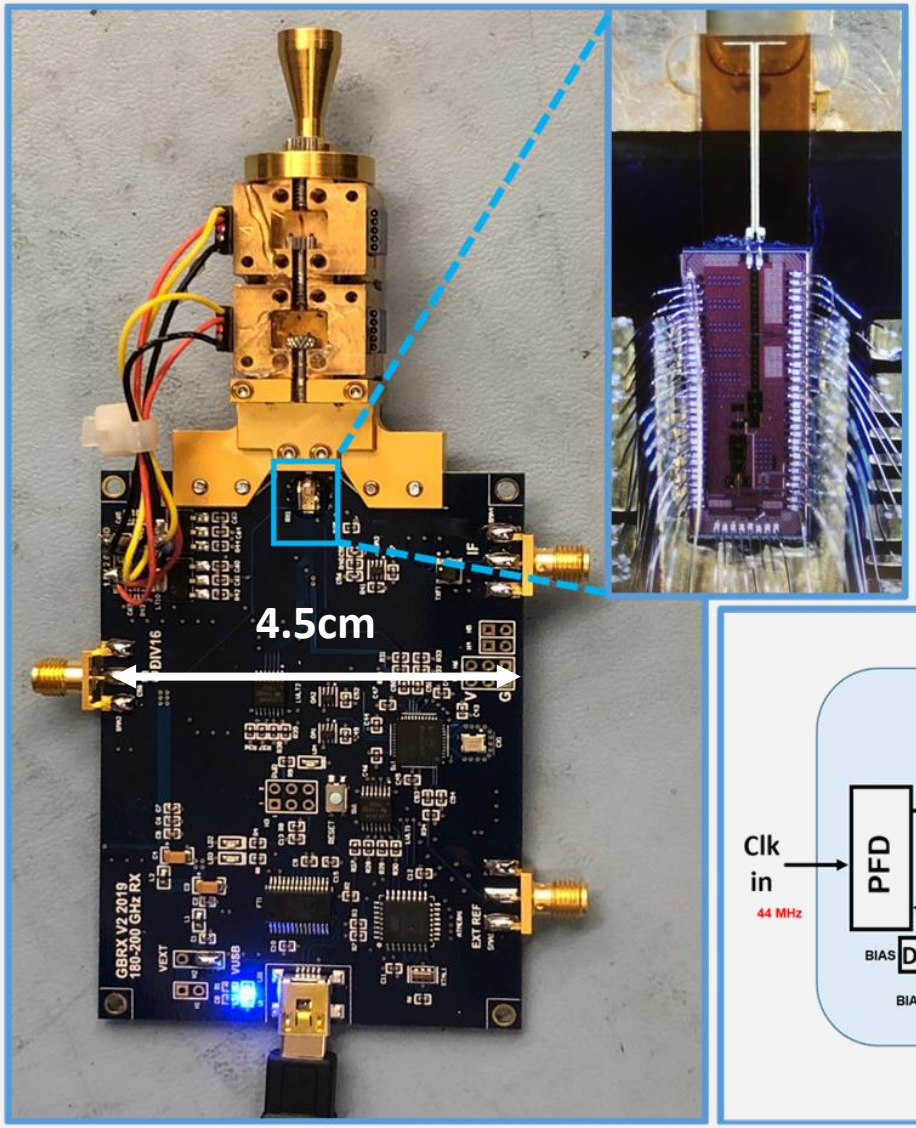
- Implementation of a full microwave radiometer directly on a CMOS chip with support computer / microwave components.
- Of course, this is a much lower wavelength than MLS or MIRO.
- 1.1Kg and 850mW for a comparable level of sensitivity to traditional radiometers at the same wavelength.

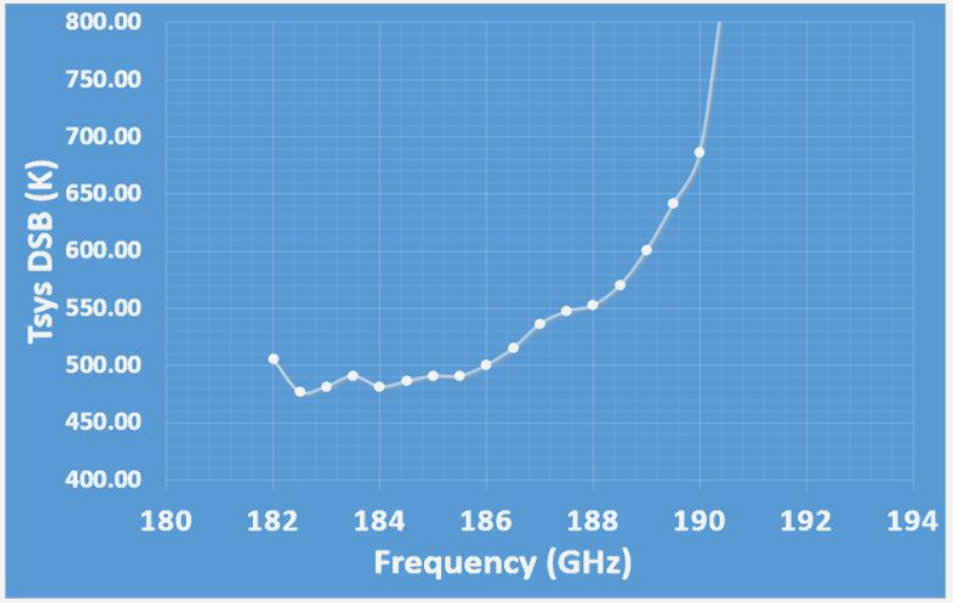
CMOS 183 GHz Spectrometer

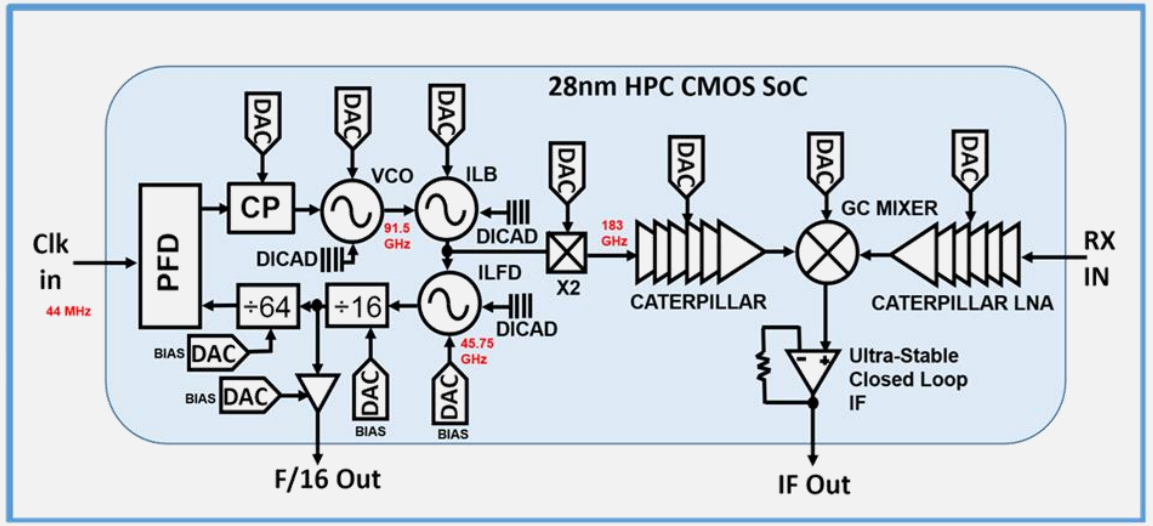


- A full 180 GHz receiver targeting the H_2O line (same as MIRO's lower band) implemented on a single chip including the LO, and RF components.

CMOS 183 GHz Spectrometer

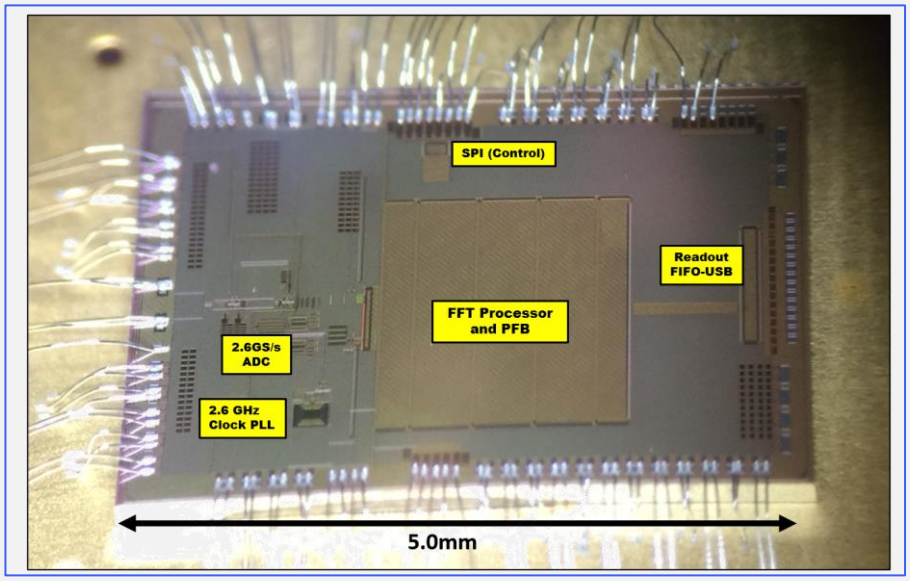


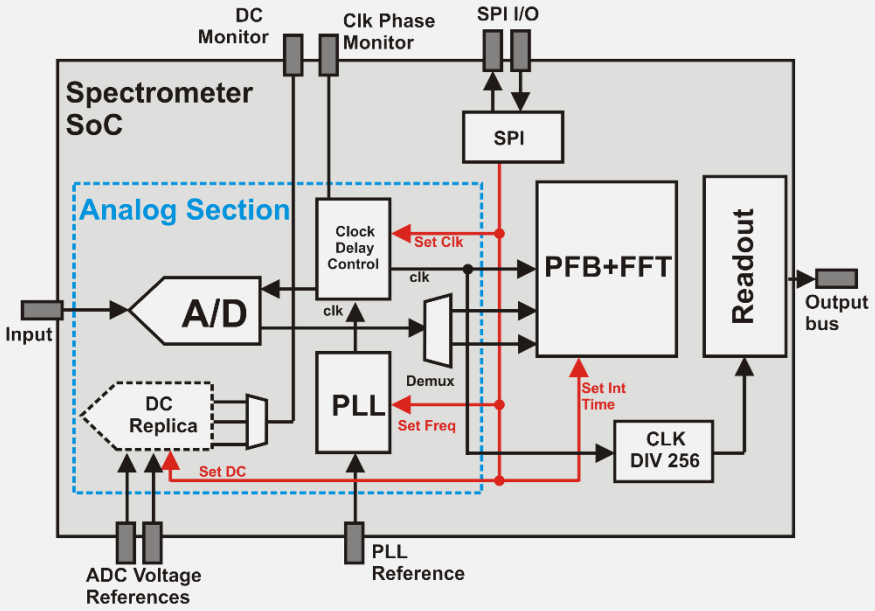


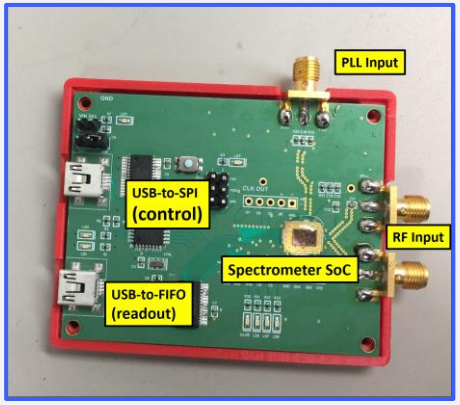


❖ **Entire receiver module is 150g and 0.5W with comparable sensitivity.**

Spectrometer Processor I

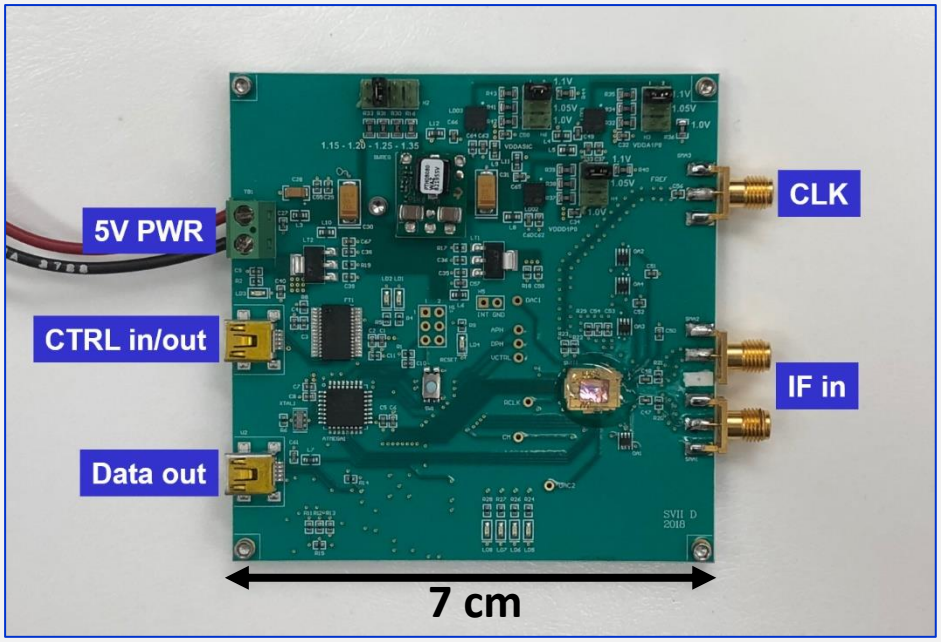


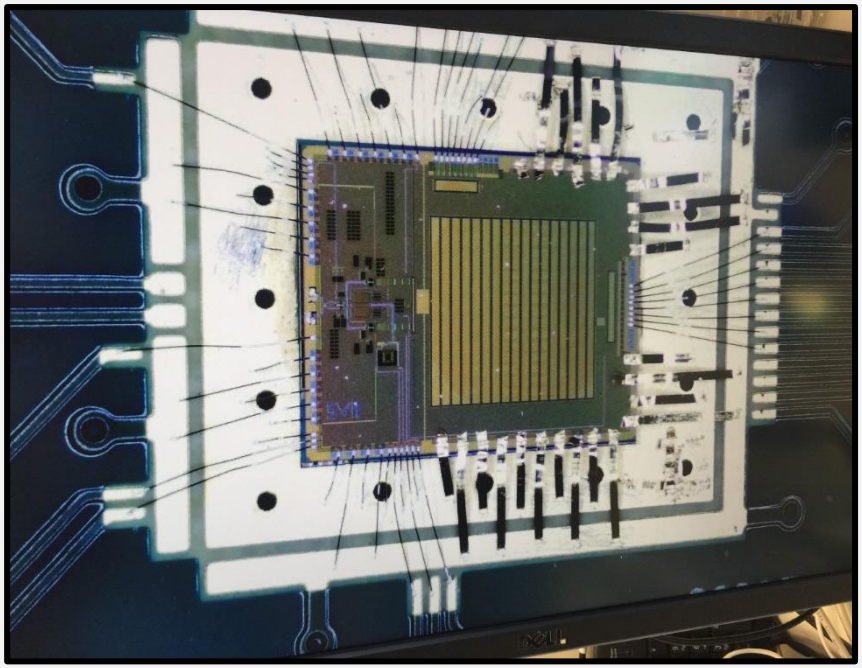




- CMOS Spectrometer processor offers a 2048 point FFT processor with integrated ADCs providing 3.0 GS/s of acquisition as well as a wide range of clock and ADC calibration to accommodate radiation effects and extreme temperatures.
- Power consumption is 1.5W and mass is 150g.

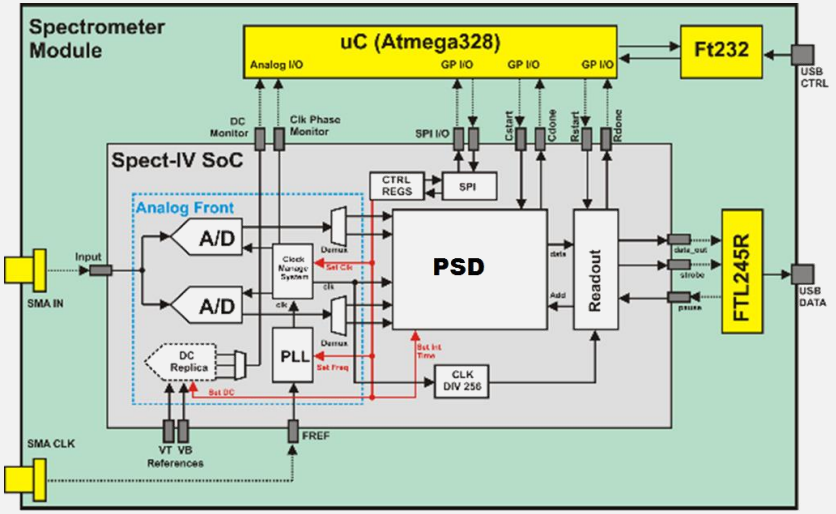
Spectrometer Processor II





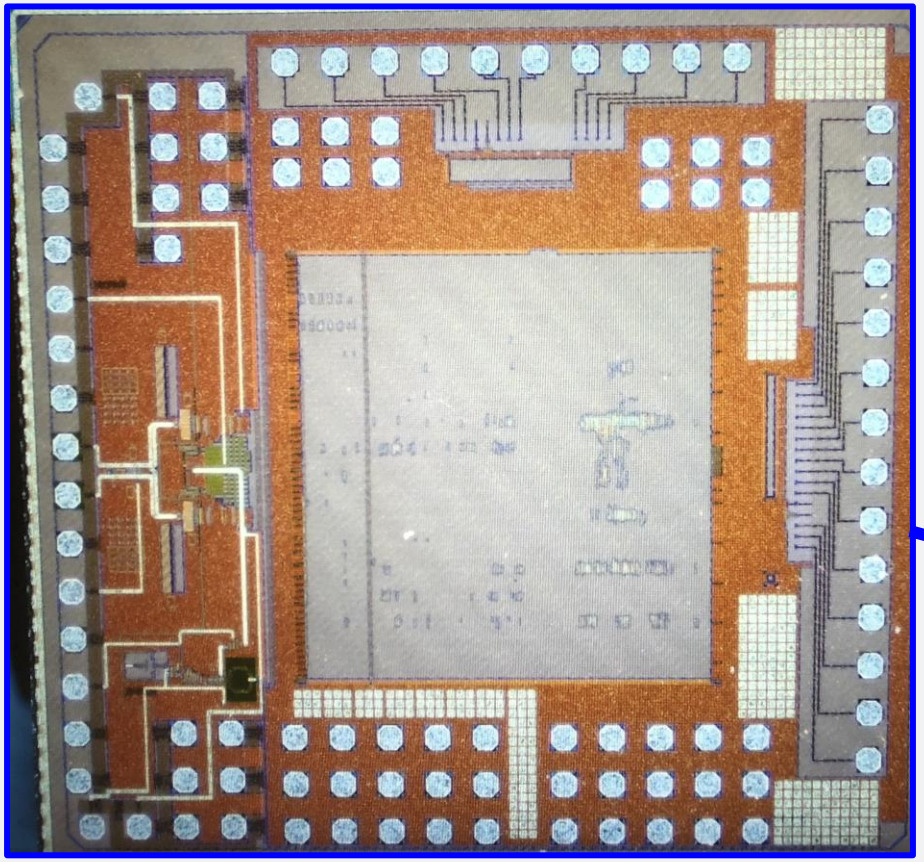
- Finished the second generation of CMOS spectrometer processor offers a 8192 point FFT processor with integrated ADCs providing 6.0 GS/s of acquisition as well as a wide range of clock and ADC calibration to accommodate radiation effects and extreme temperatures.

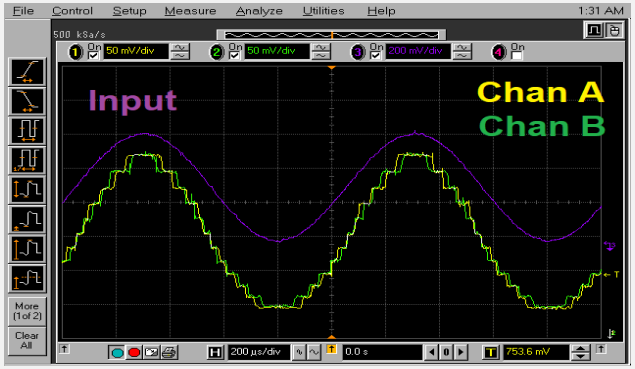
- Power consumption is 1.5W and mass is 150g.

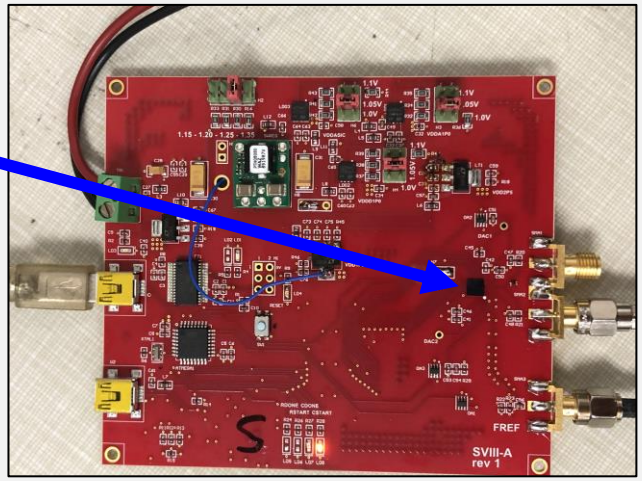


Spectrometer Processor III

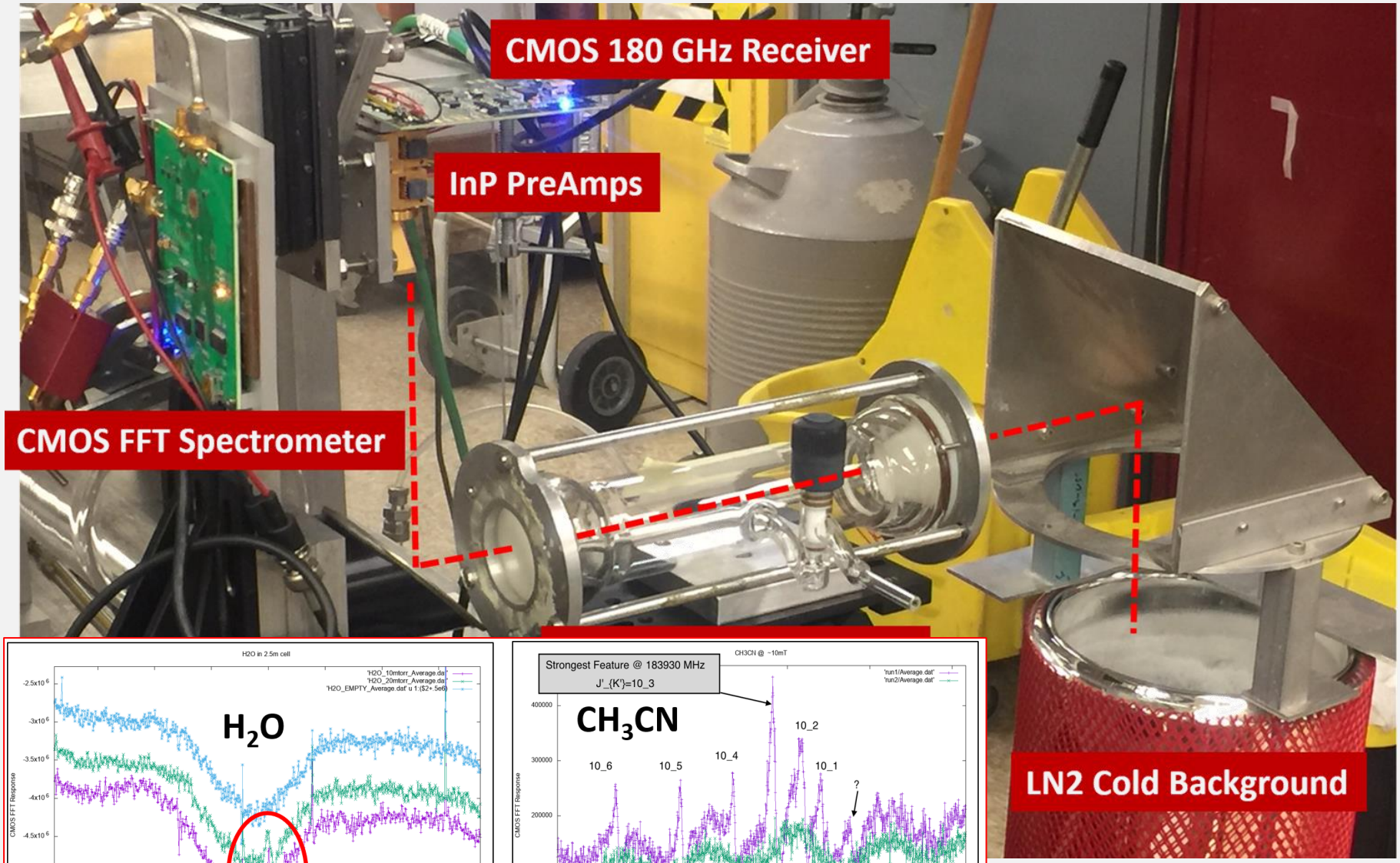
- Currently developing the third generation of CMOS spectrometer processor offers a 16384 point FFT processor with integrated ADCs providing 12.0 GS/s of acquisition as well as a wide range of clock and ADC calibration to accommodate radiation effects and extreme temperatures.
- Planned to be used in several astronomy radio-telescopes!



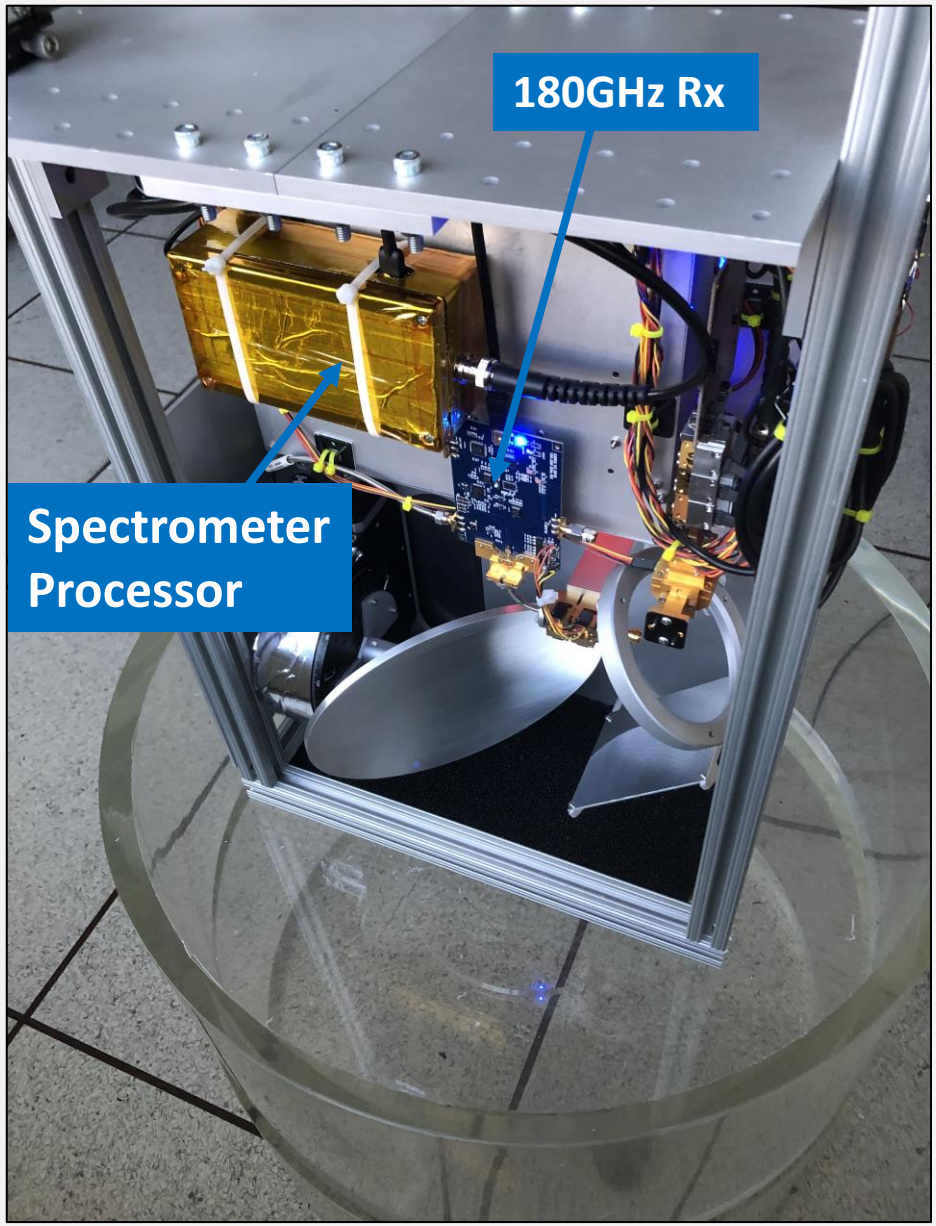


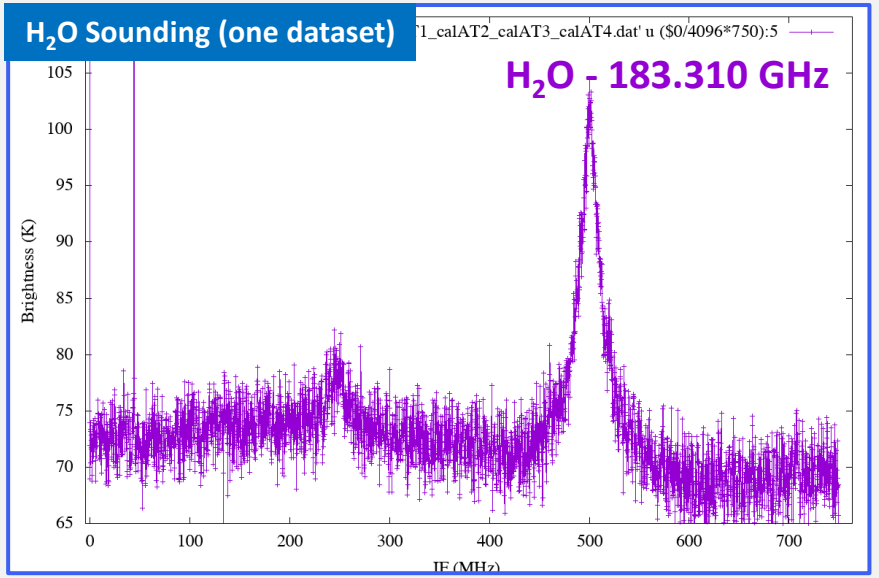


183 GHz Lab Demonstration



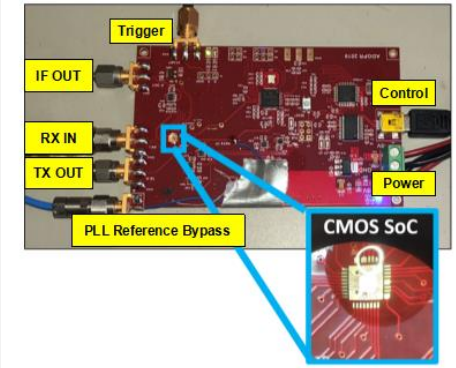
183 GHz Sub-Orbital Demonstration

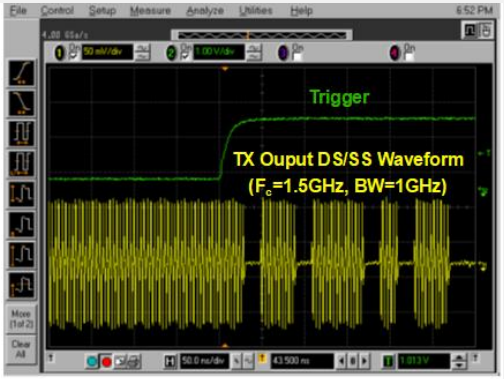


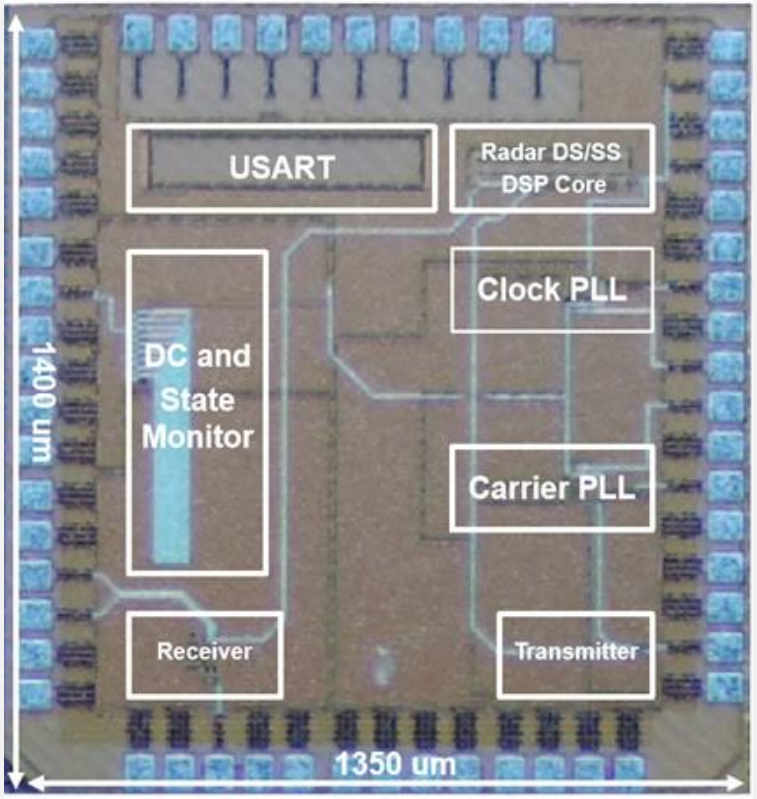


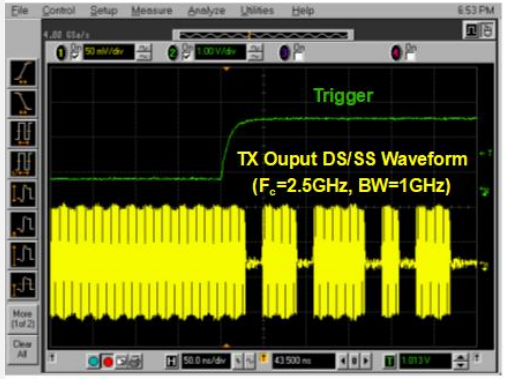
CMOS Radars

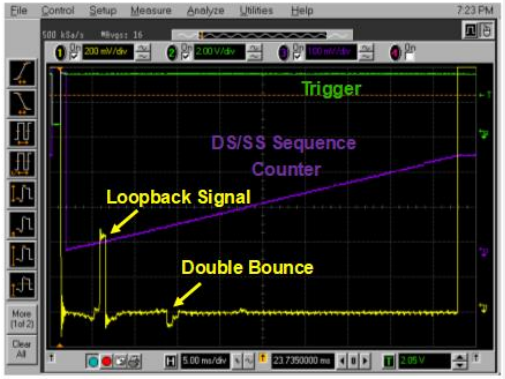
All-Digital Ground Penetrating Radar







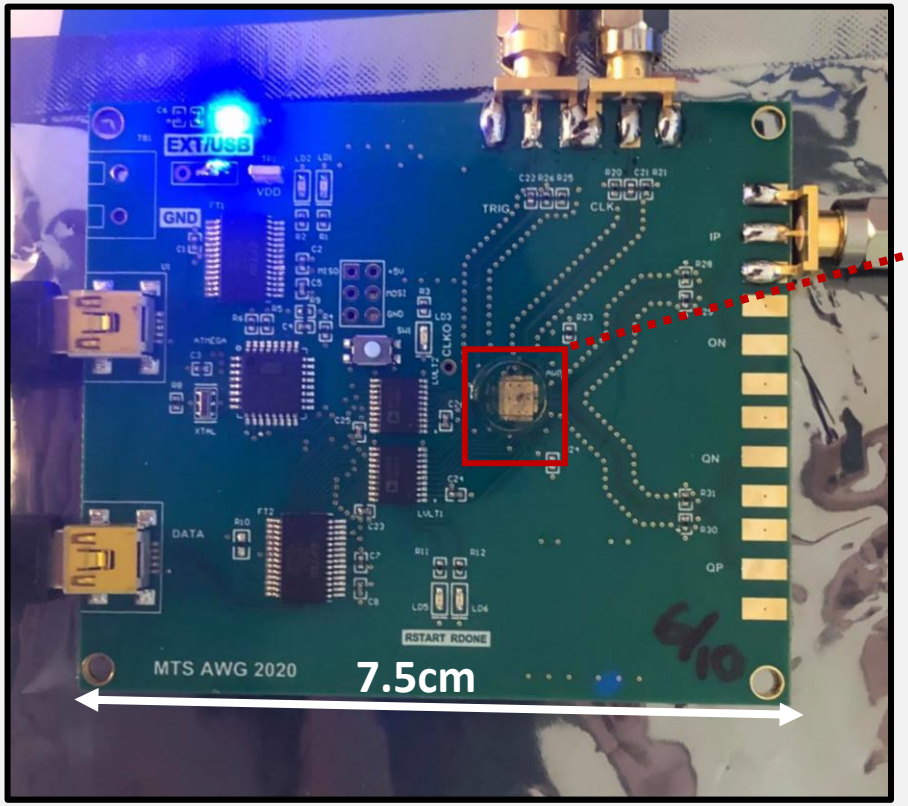


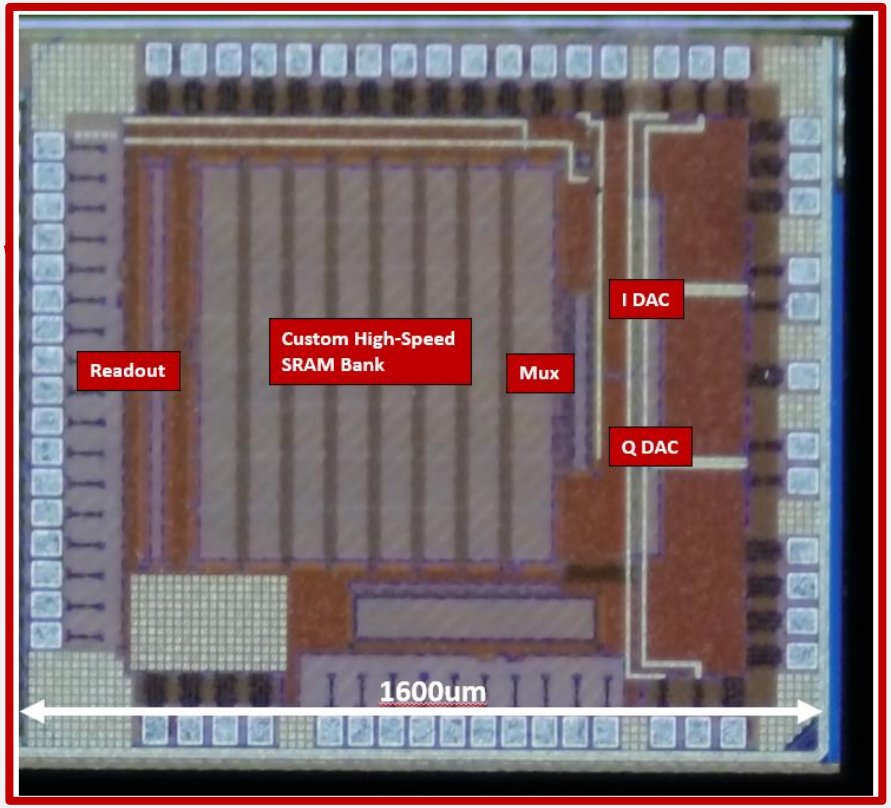


- Developing an all-digital spread-spectrum radar for in-situ exploration of the sub-surface remote planetary bodies. Mass is 200g and power of 1.5W.

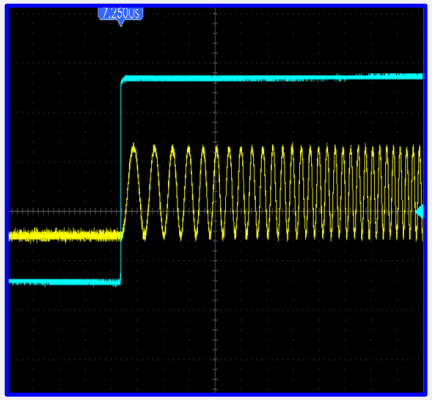
- Unlike an RF radar, all the parameters (wavelength, bandwidth, integration time, resolution, penetration depth) are programmable from the ground since there are no fixed components.

Almost-All Digital GPR Chipset

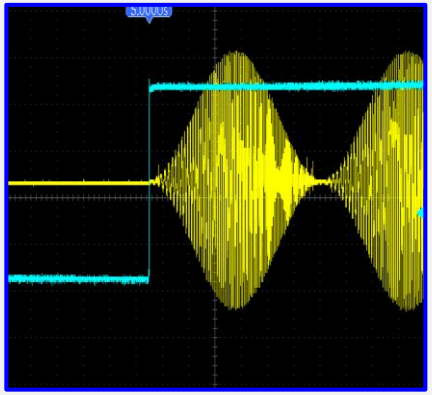




FMCW Mode

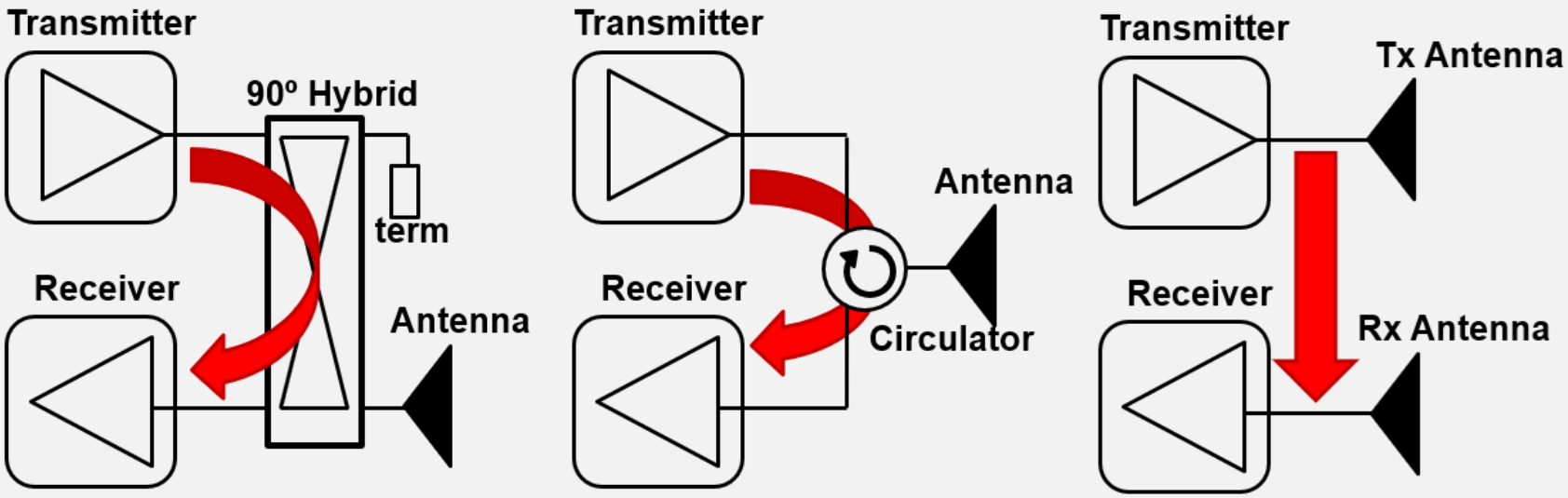


Pulse Compression

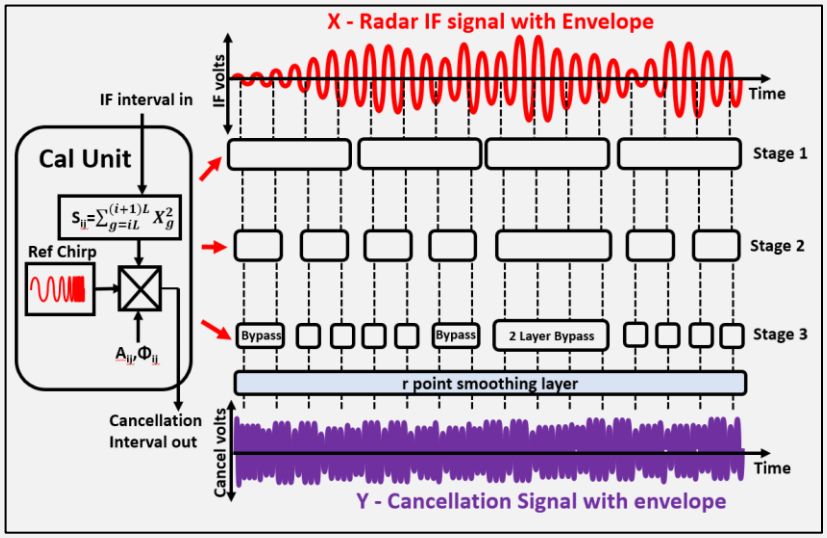


- Also developed a similar almost all digital radar which allows for slightly higher dynamic range/sensitivity than the all digital one at the cost of one analog component. Also 200g and 1.5W.

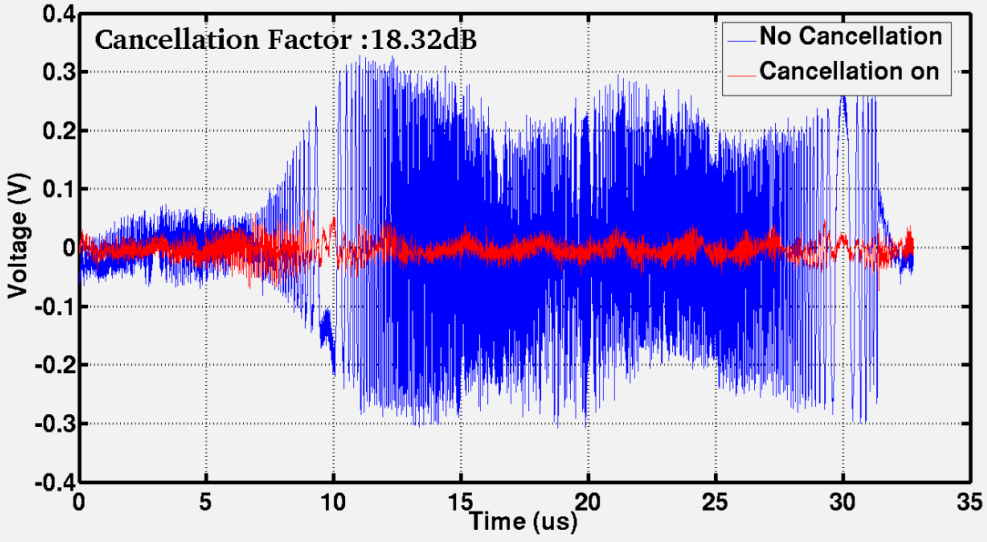
GPR Self-Leakage Solutions



AI Engine:

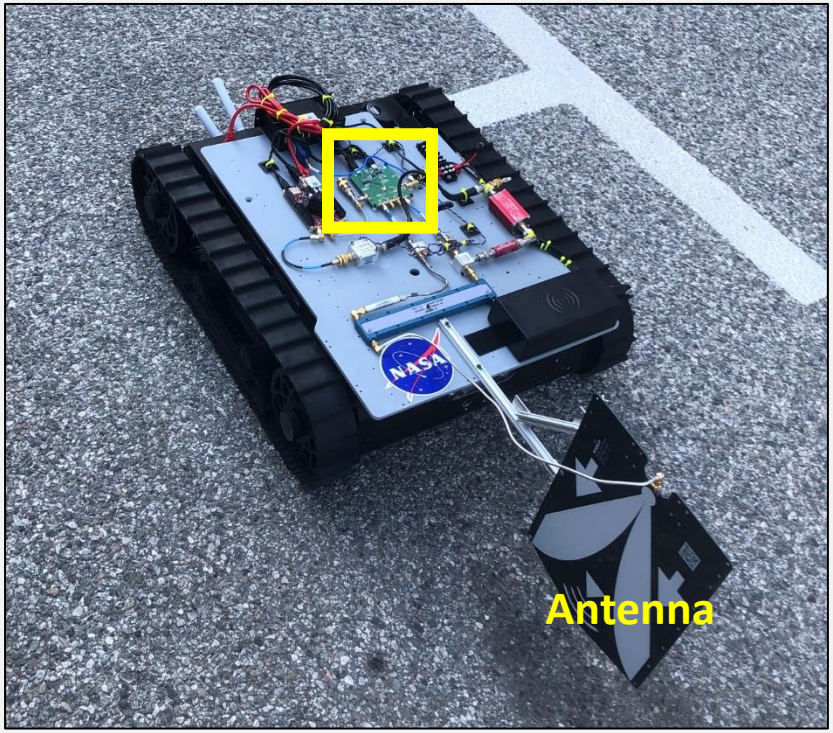


Leakage Improvements:

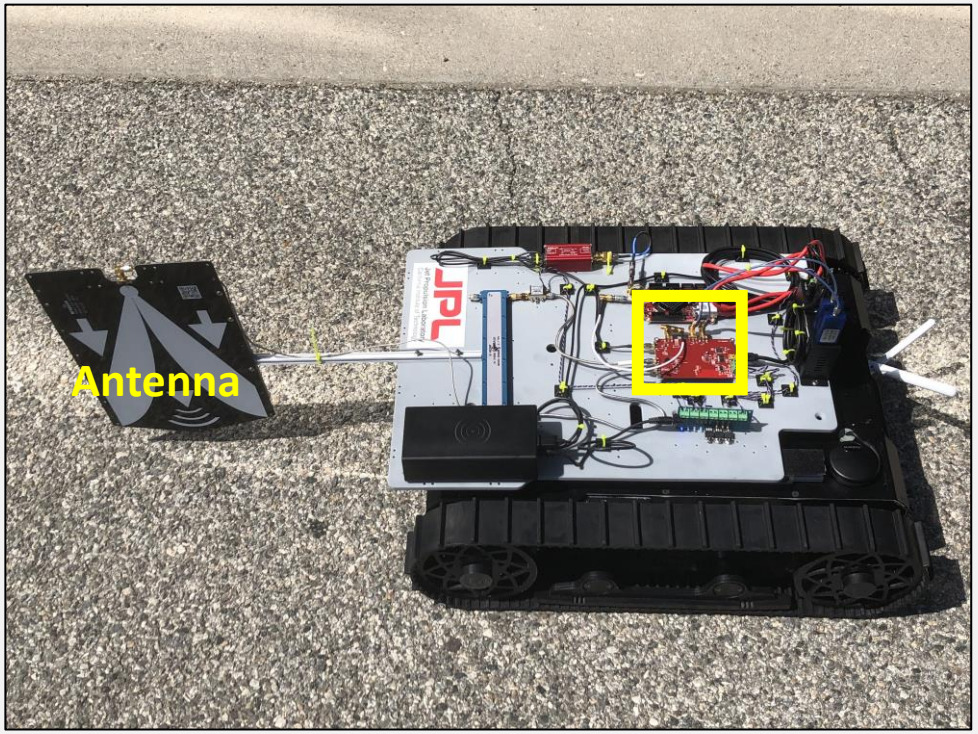


Digital Ground Penetrating Radars

Almost-All Digital Radar



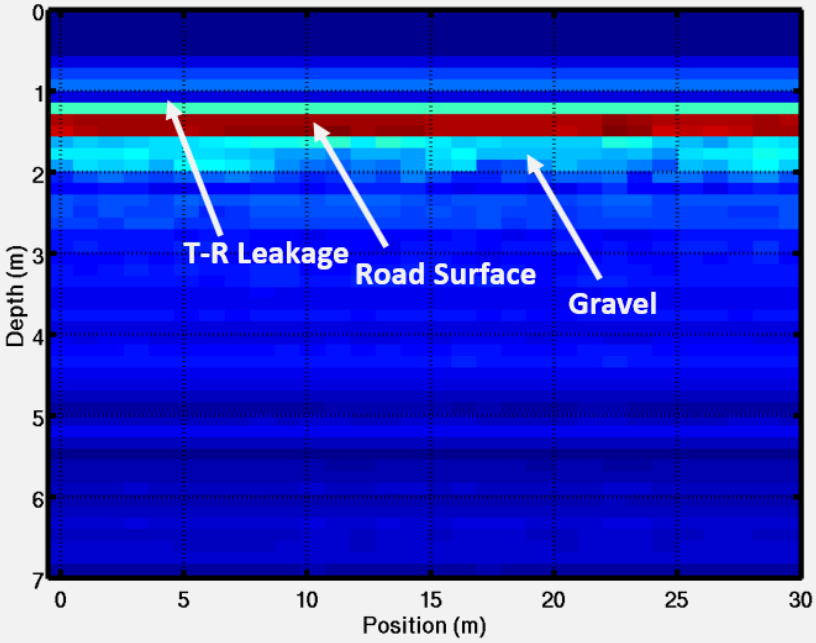
All Digital Radar



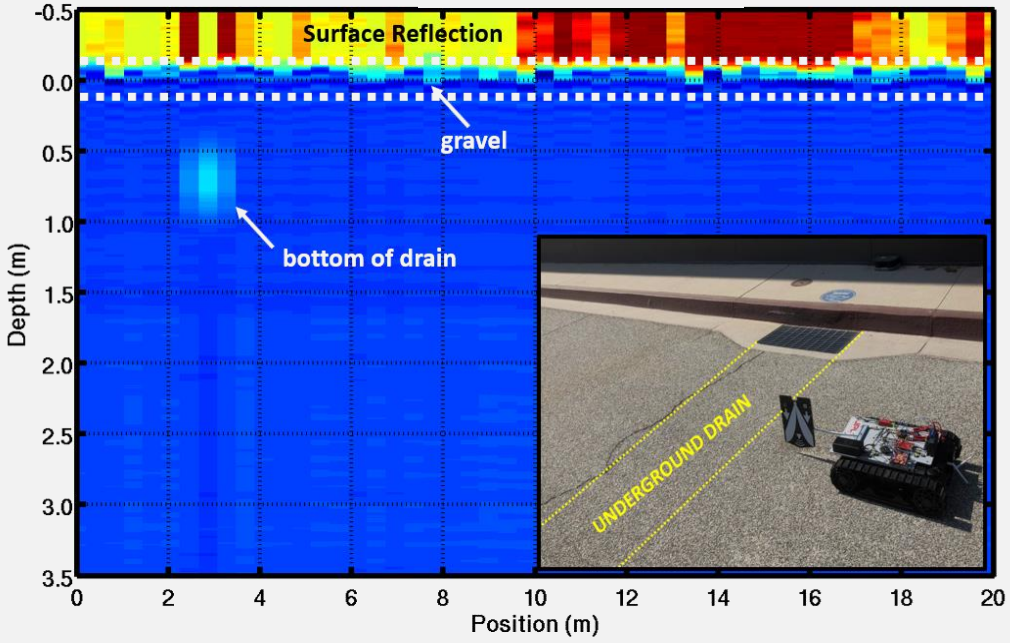
- Integrated both systems onto test rovers with an appropriate antenna and have begun outdoor sub-surface testing this month.

Ground Penetrating Radar Testing

Almost-All Digital Radar



All Digital Radar



- Both GPR systems show good early results but need some fine-tuning and we also need to test somewhere with a more exciting subsurface than the middle of the road at JPL.

Thoughts to take away…

- CMOS can provide a means to miniaturize and reduce the power of space science instrumentation, but attention has to be paid to maintain the fidelity and sensitivity of the measurements they perform.

- Bringing CMOS technology to science instruments allows compact platforms an avenue to doing science investigations that may otherwise be prohibitive in either payload resources (mass and power) or mission cost.