A Low-Volume, Low-Mass, Low-Power UHF Proximity Micro-Transceiver for Mars Exploration

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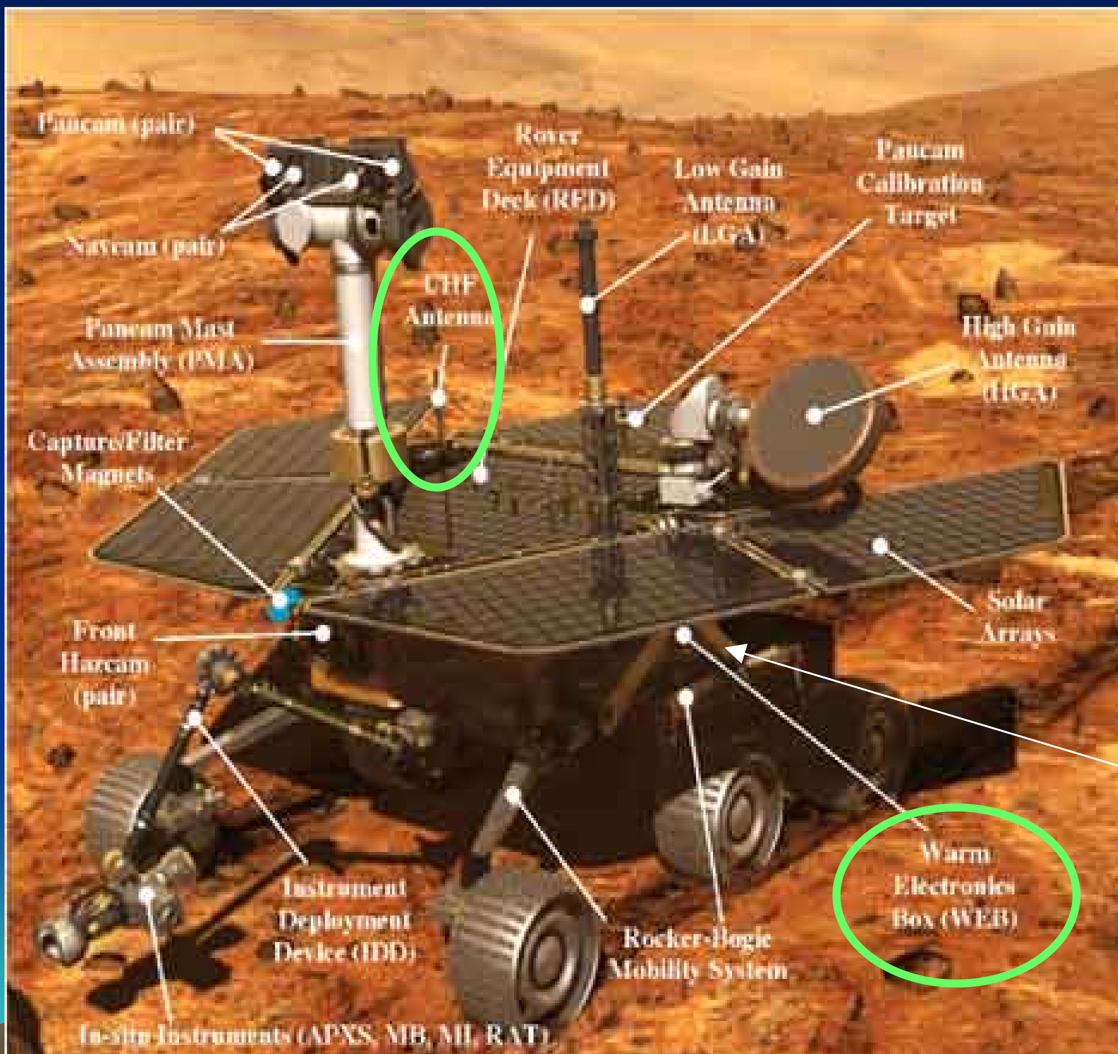
Existing Transceivers

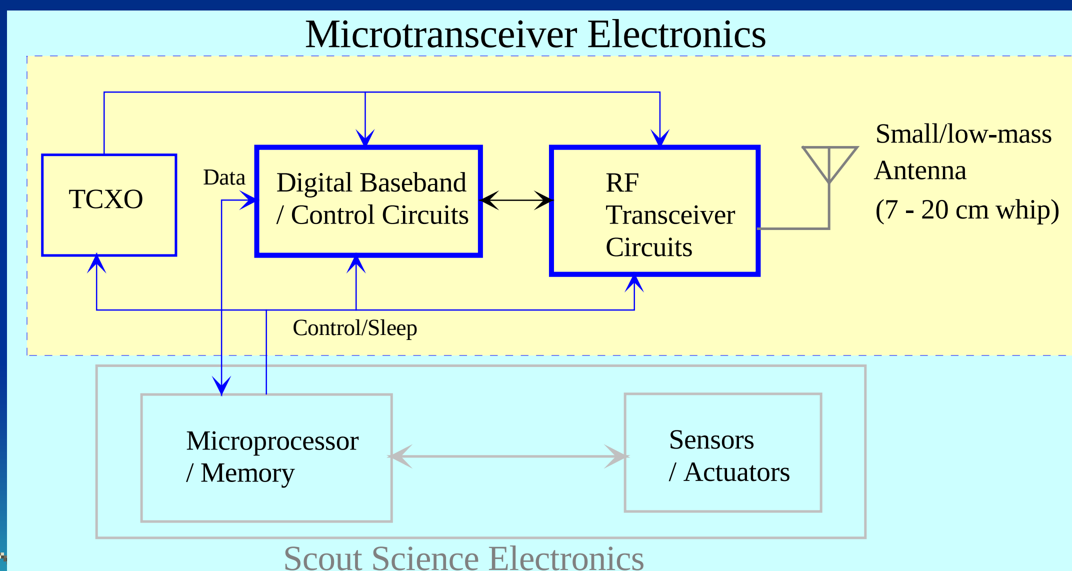


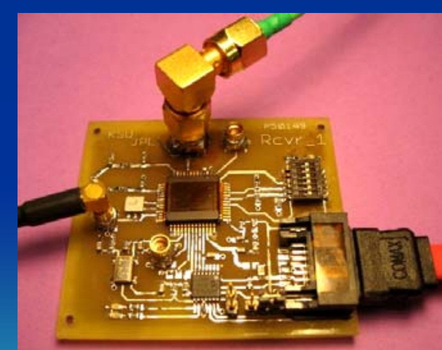
- Full-duplex, 401.585 MHz tx, 437.1 rx
- PSK or FSK modulation
- Sensitivity: -124 dBm @8kbps
- RF output power 10W
- Size: 6.7” x 5.1” x 3.6”
- Mass: 2kg
- Power: 45W tx, 5W rx

Source:
http://www.cinele.com/505.htm

Micro-transceiver Overview

A highly-miniaturized, extremely low-mass, low-power UHF transceiver module for aerobots, microrovers, low-mass penetrators and small network landers.





Microtransceiver Goals

<table>
<tr><th><u>Goals</u></th><th><u>Significance</u></th></tr>
<tr><td>

- Reduce mass, volume, and power

<table>
<tr><th></th><th>C/TT-505</th><th>Microtransceiver</th></tr>
<tr><td>Mass</td><td>2000 gms</td><td>< 10 gms (PCB)</td></tr>
<tr><td>Volume</td><td>2000 cm^3</td><td>< 10 cm^3</td></tr>
<tr><td>Power (RF out)</td><td>10 W</td><td>0.01 / 0.1 / 1 W</td></tr>
<tr><td>P_{DC} (RX/TX)</td><td>5 W / 45 W</td><td>0.05 W / .1 to 3 W</td></tr>
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- Offers enabling technology for new classes of scouts, including aerobots, balloons, networked micro-rovers…
- Reduced mass/cost on larger scouts with lower data rate requirements and half-duplex operation.

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- Provide compatibility with Prox-1 communications infrastructure.

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- Permits adoption in near-term mission hardware (e.g. 2011 scouts).

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- Produce working prototype to TRL-6, targeting –100C and 100 krad tolerance

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- Eliminates need for warm-box and shielding, reducing launch costs, etc.

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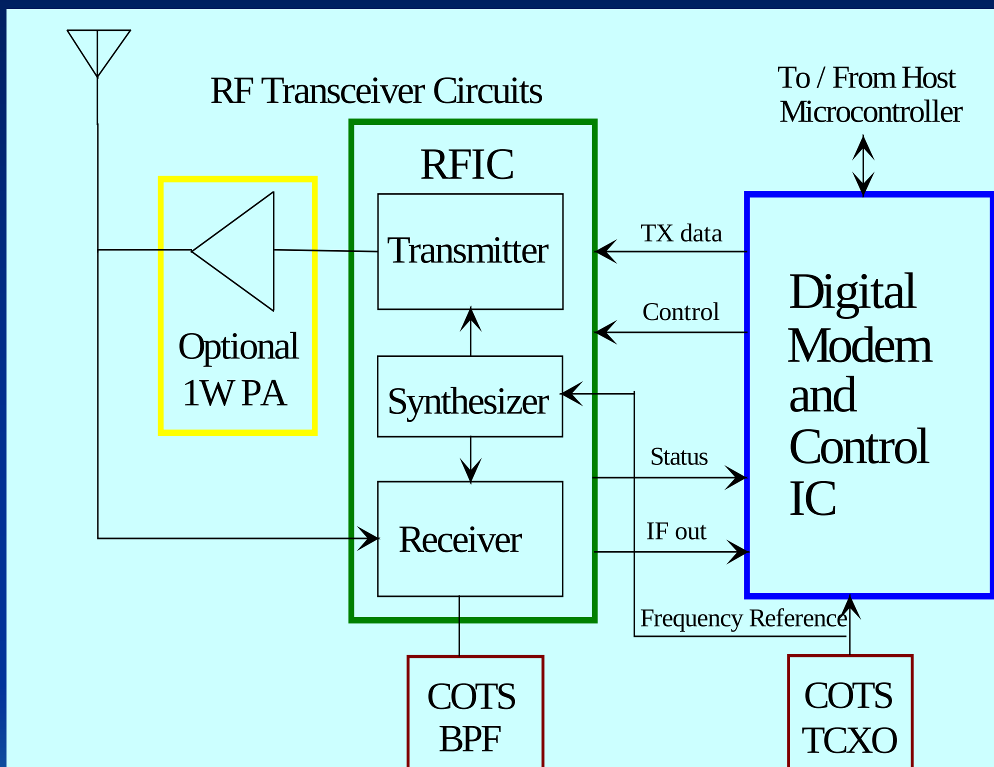
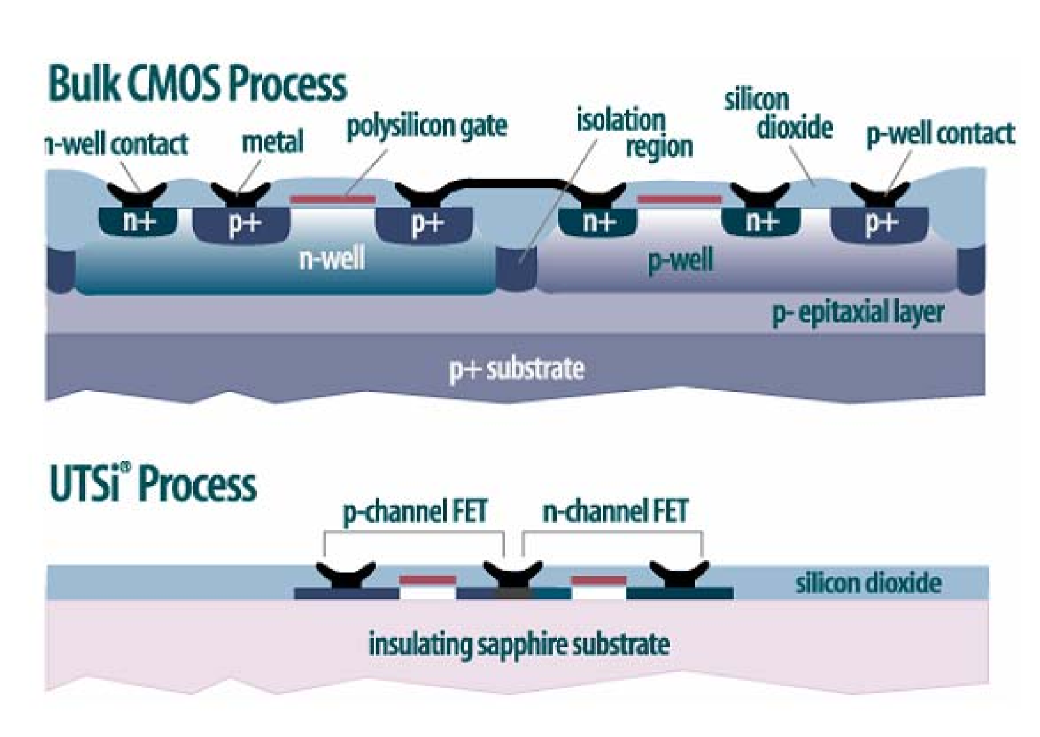
Top-Level Block Diagram



- Design employs a two / three chip solution for 10,100 mW / 1 Watt output.
- Off-chip components limited to Commercial Off-the-shelf (COTS) IF filter and TCXO
- Targets subset of Prox-1 protocols (half-duplex, asymmetric data rates)
- Circuits characterized to –100 C to enable operation outside warm-box in some applications
- Employs rad-hard process and digital library.

Implementation Techniques

Peregrine Silicon-on-Sapphire “Ultra-Thin Silicon” IC process employed.



- 0.5um (0.25um available)
- Low parasitics => high fT
- No substrate losses/coupling
- Excellent quality inductors
- 6 flavors of FETs
- MiM capacitors
- MOSFET varactors
- Suitable for digital / analog / RF
- Radiation-hardened “FO” flavor available

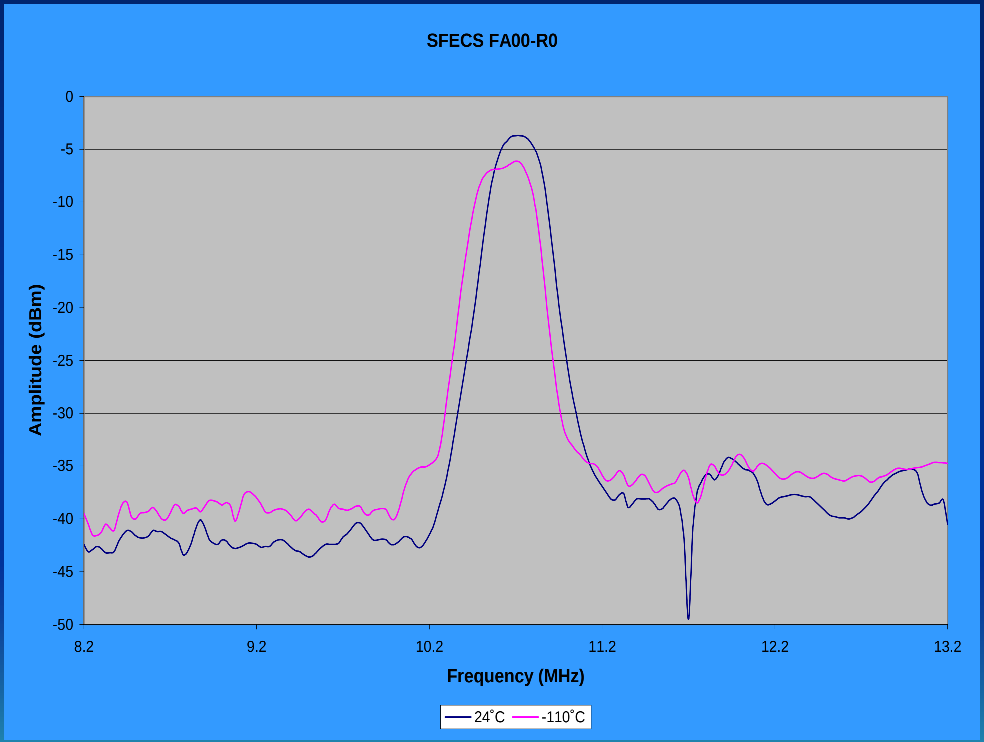
Implementation Techniques

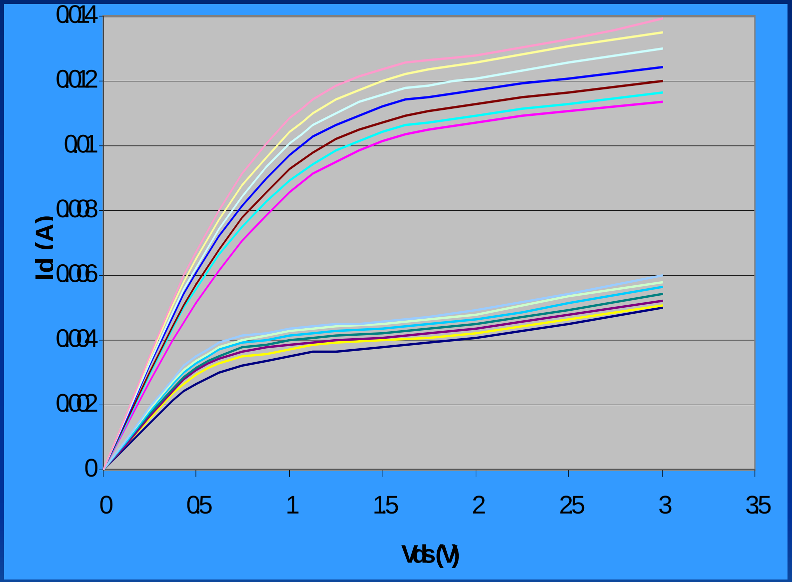
Cryogenic platform developed at K-State for pre-design characterization of COTS parts and IC process components to < –100 C.

Low-Temp Test Results

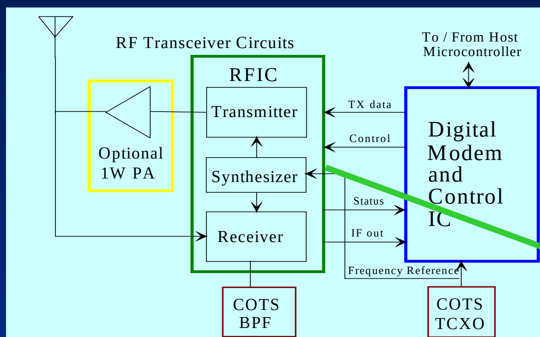
Sample Cryogenic Test Results

Detailed results presented at 6:30pm poster session.

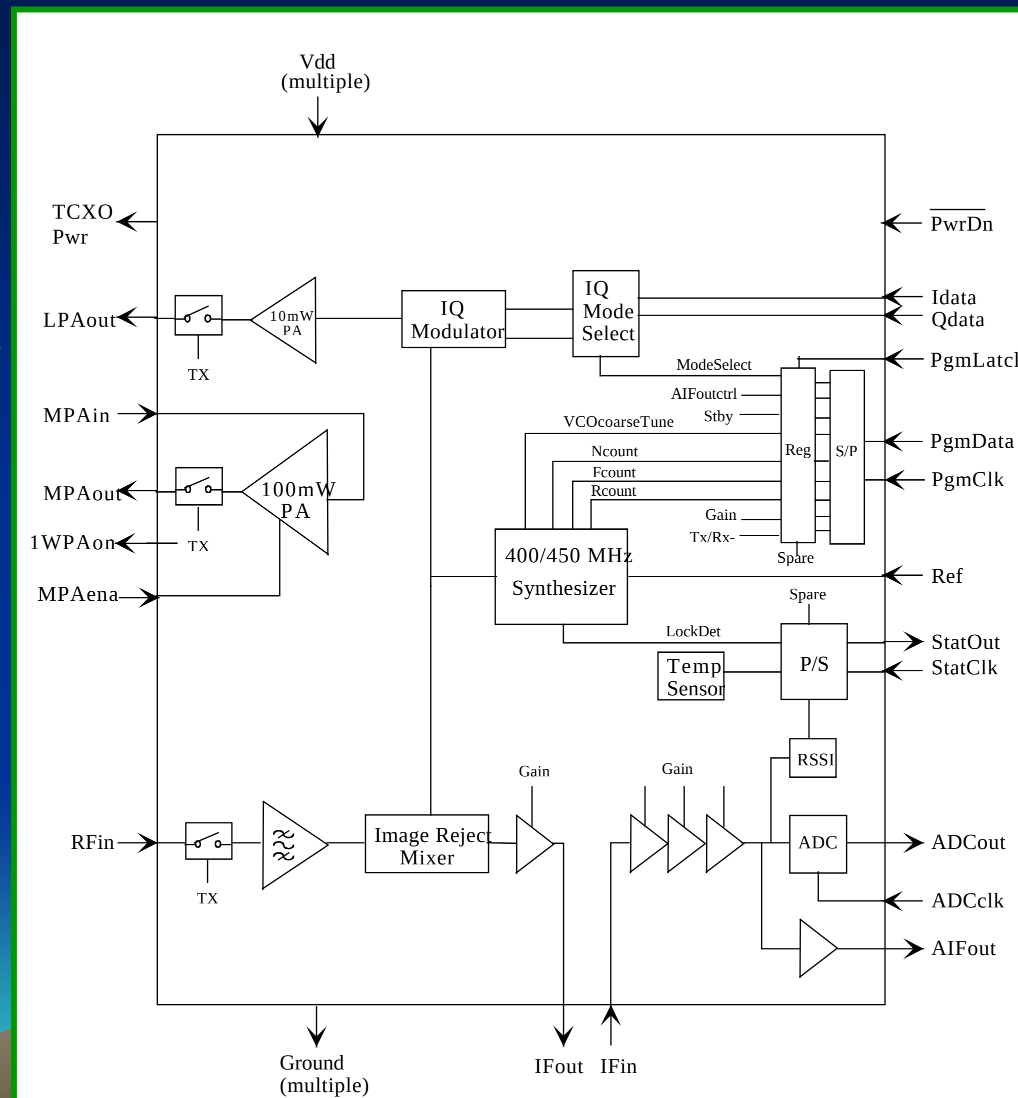




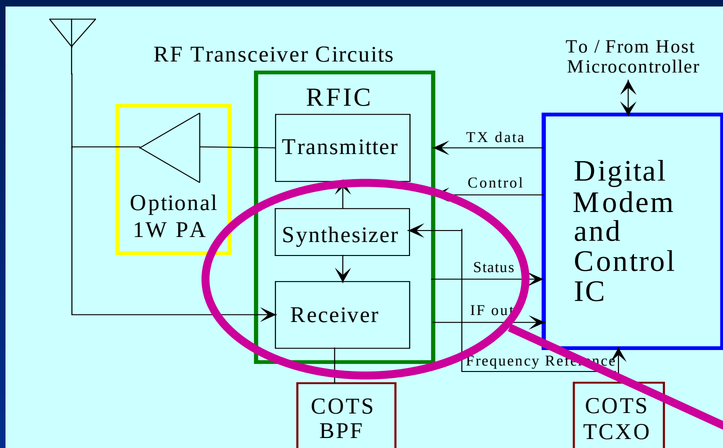
RFIC Development

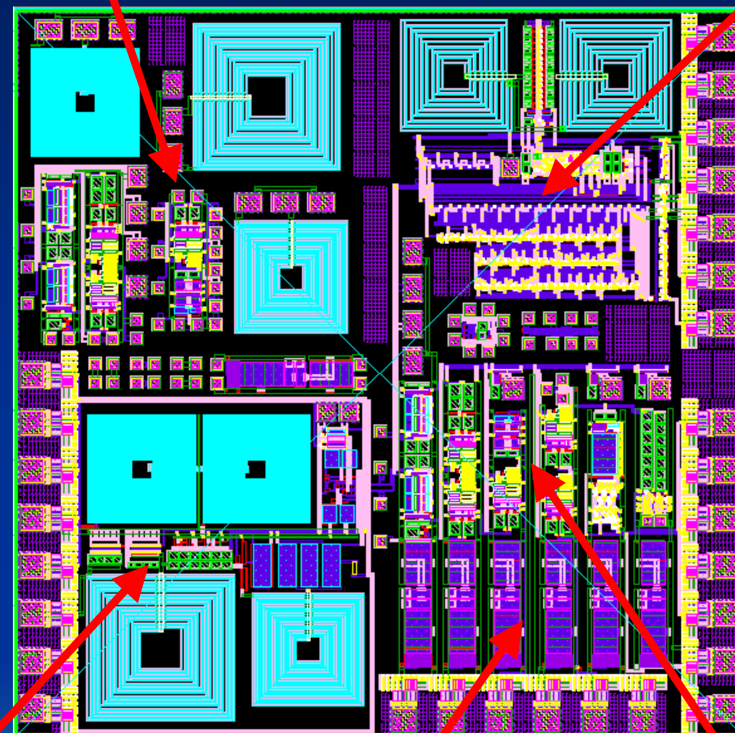


- Proven architectures employed (superhet receiver and direct modulation transmitter)
- Iterative fabrication runs to test and center designs
- Transmitter employs large size, high-Q inductors to achieve good efficiency
- Receive trades off IP3 and compression performance for low power
- Half-duplex operation allows transmitter and receiver on same die
- IF sampling and companion digital modem IC provides high-quality demodulation



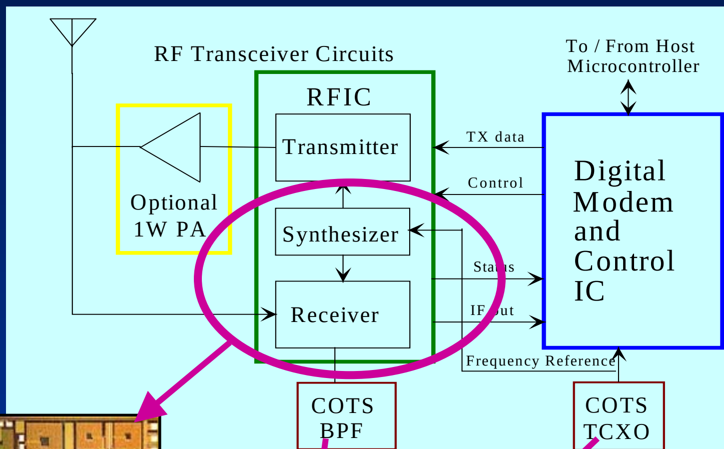
Fab 1 Receiver RFIC Circuits Operational



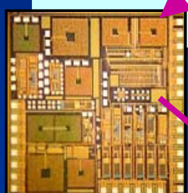


- –Integer-N Synthesizer
- –LNA + TR switch
- –Image-reject mixer
- –IF amplifiers
- –Amplitude detector
- –1-Bit ADC
- –Extensive supply filtering
- –Stand-alone test structures
- –Probe points

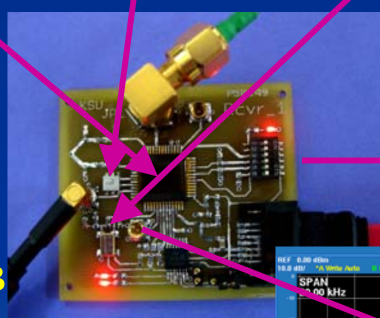
Fab1 Receiver RFIC Testing



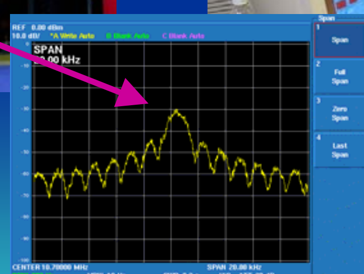
- Fab-1 die includes all major receiver blocks
- Successfully tested from RF-in to sampled IF-out
- Low temperature testing shows nominal behavior to –100C with low parametric drift
- Identified areas needing improvement in subsequent fabs to fully meet performance goals:
  1. *Improve LNA gain to achieve system NF spec*
  2. *Provide finer tuning steps and reduce spurs*



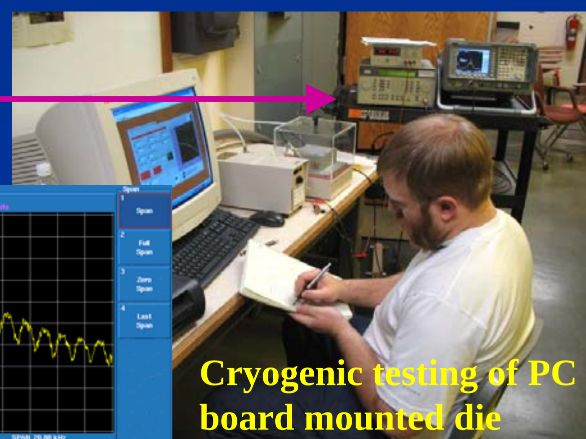
Fab1 die



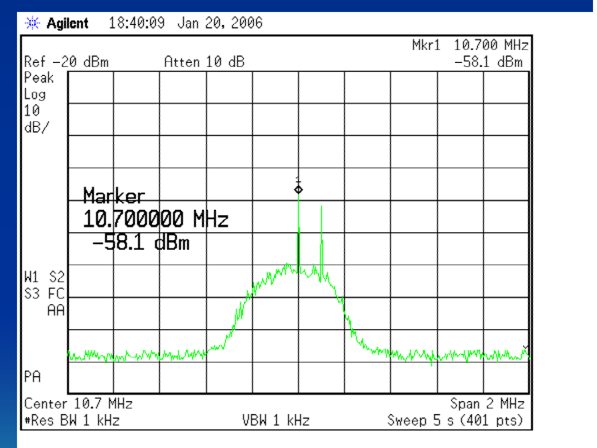
Packaged die on PCB



Spectrum of 1-bit ADC output (1.5 ksps QPSK)

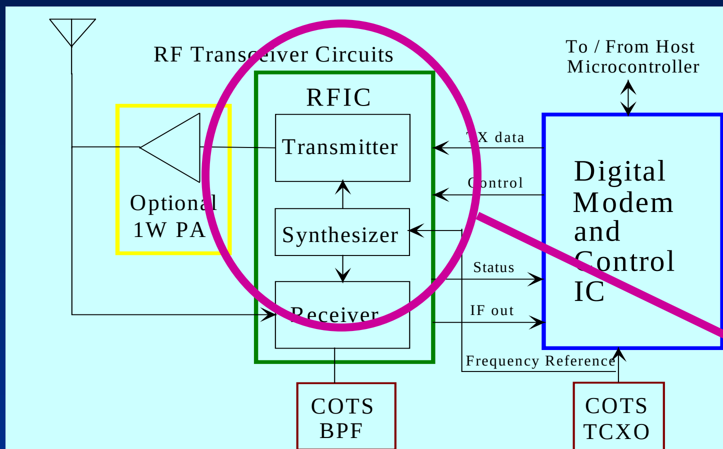


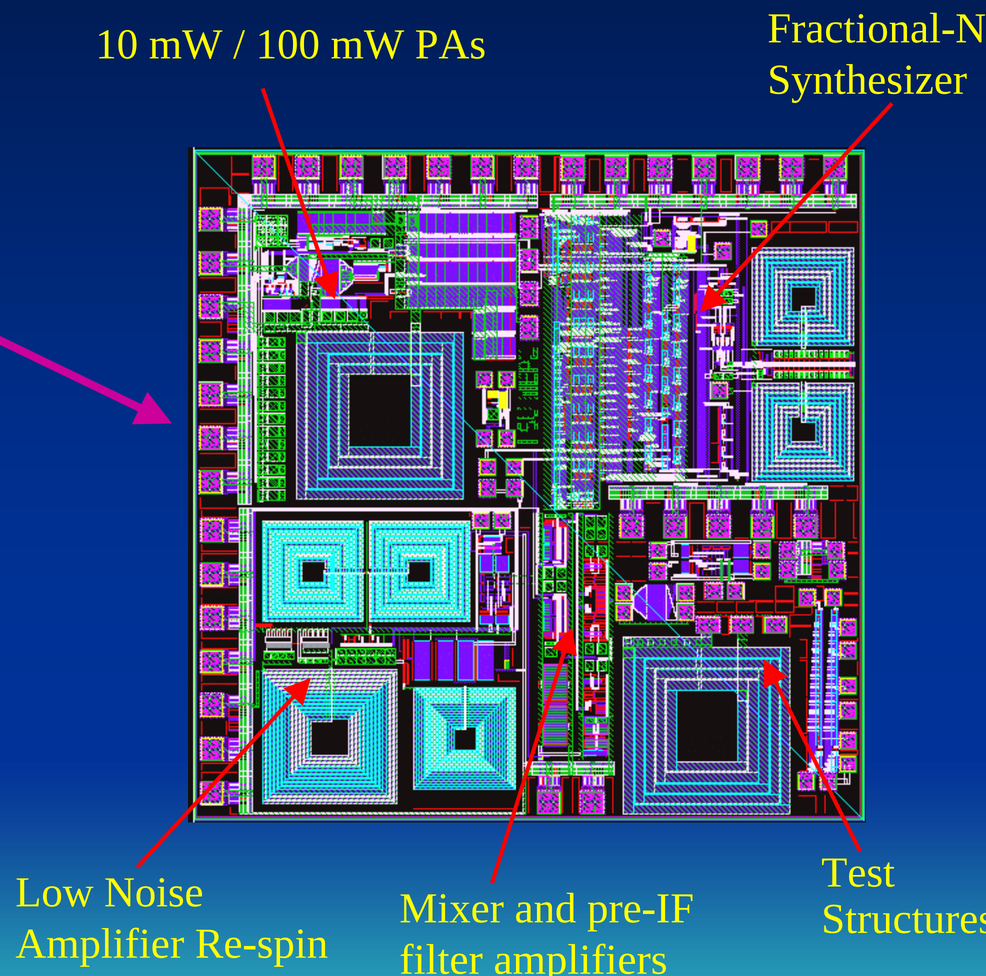
Cryogenic testing of PC board mounted die



IF filter output from +25 C to –100 C with –100 dBm unmodulated carrier.
(reference harmonic spur visible to right)

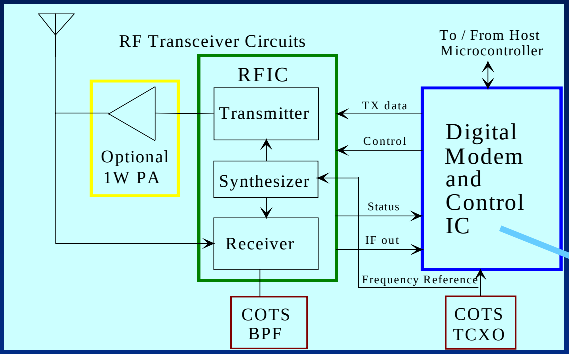
Fab2 Transmitter Circuits Operational

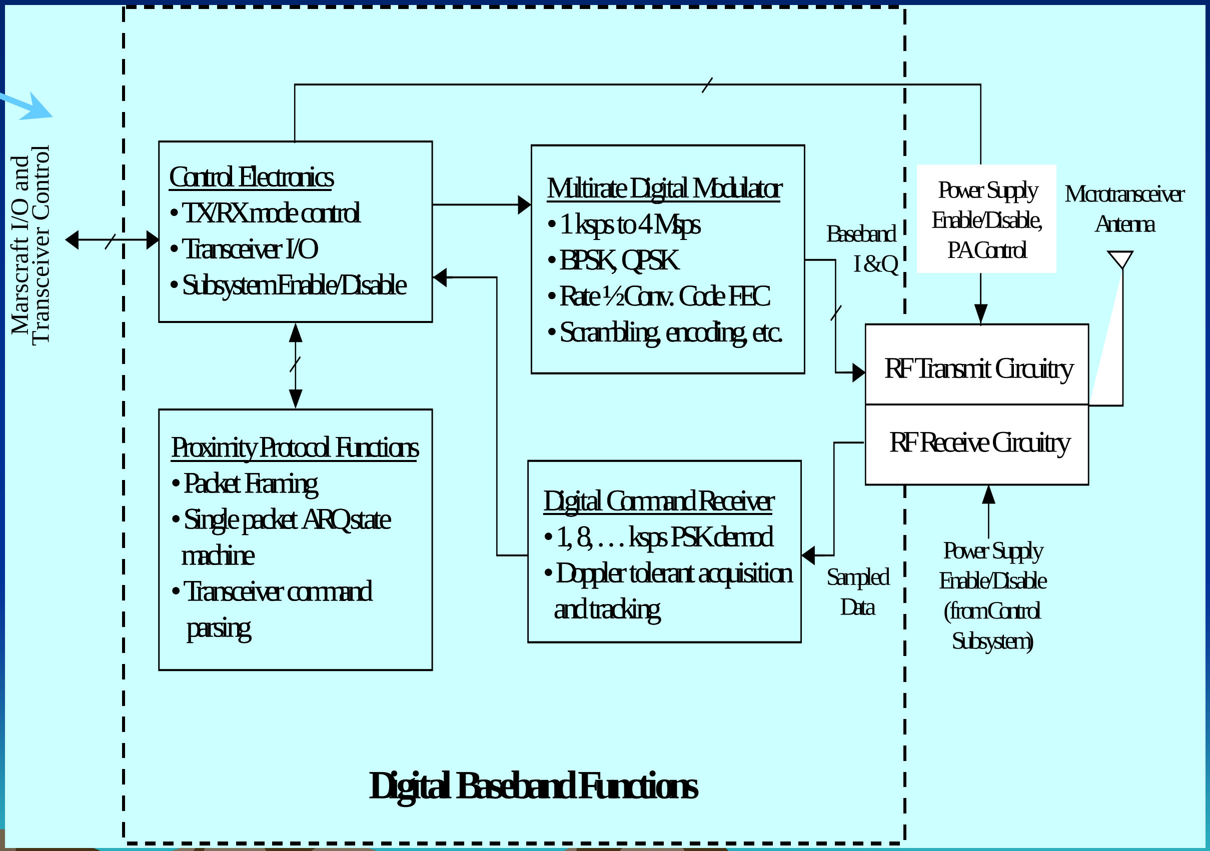




- Improved synthesizer with dual-modulus prescaler and 3rd-order MASH fractional-N fine tuning
- First-spin design of 10mW and 100 mW PA circuits
- LNA re-spin with 15 dB additional gain to fix system NF issues from fab 1
- Test structures including temperature sensor

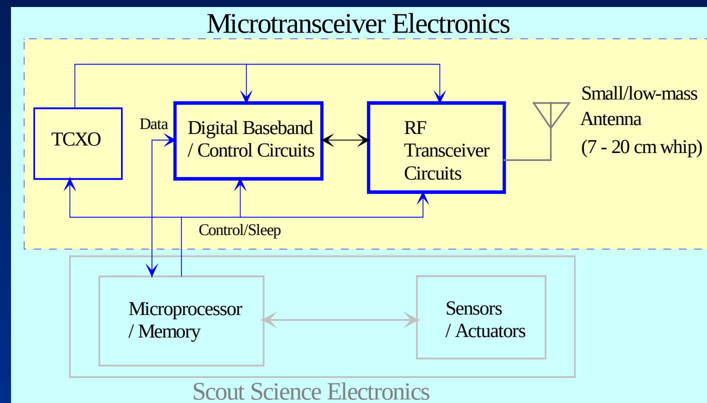
Digital Modem IC Development

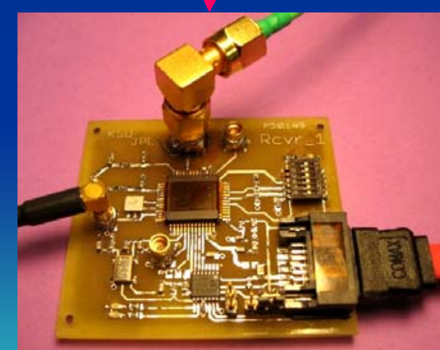




Summary

This project targets a highly-miniaturized, extremely low-mass, low-power UHF transceiver module for aerobots, microrovers, penetrators and small network landers.





- First prototype RFIC receiver and transmitter circuits are operational and critical demodulator digital circuits have been prototyped in Matlab and Verilog
- Final version will provide TRL6 validation of Prox-1 compatible micro-transceiver with 100X reduction in mass and volume and > 10:1 reduction in power consumption (for low rate applications) relative to existing solutions.

Acknowledgements and Additional Info

Acknowledgements:

- Igor Kuperman, JPL
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- Xin He, K-State / Philips
- Jeongmin Jeon, K-State
- Kai Wong, K-State
- Mark Hartter, K-State
- Evan Cullens, K-State
- Keith Kovala, K-State

Project Web Sites:

- www.eece.ksu.edu/research/mars (public)
- www.eece.ksu.edu/research/microtransceiver (private)