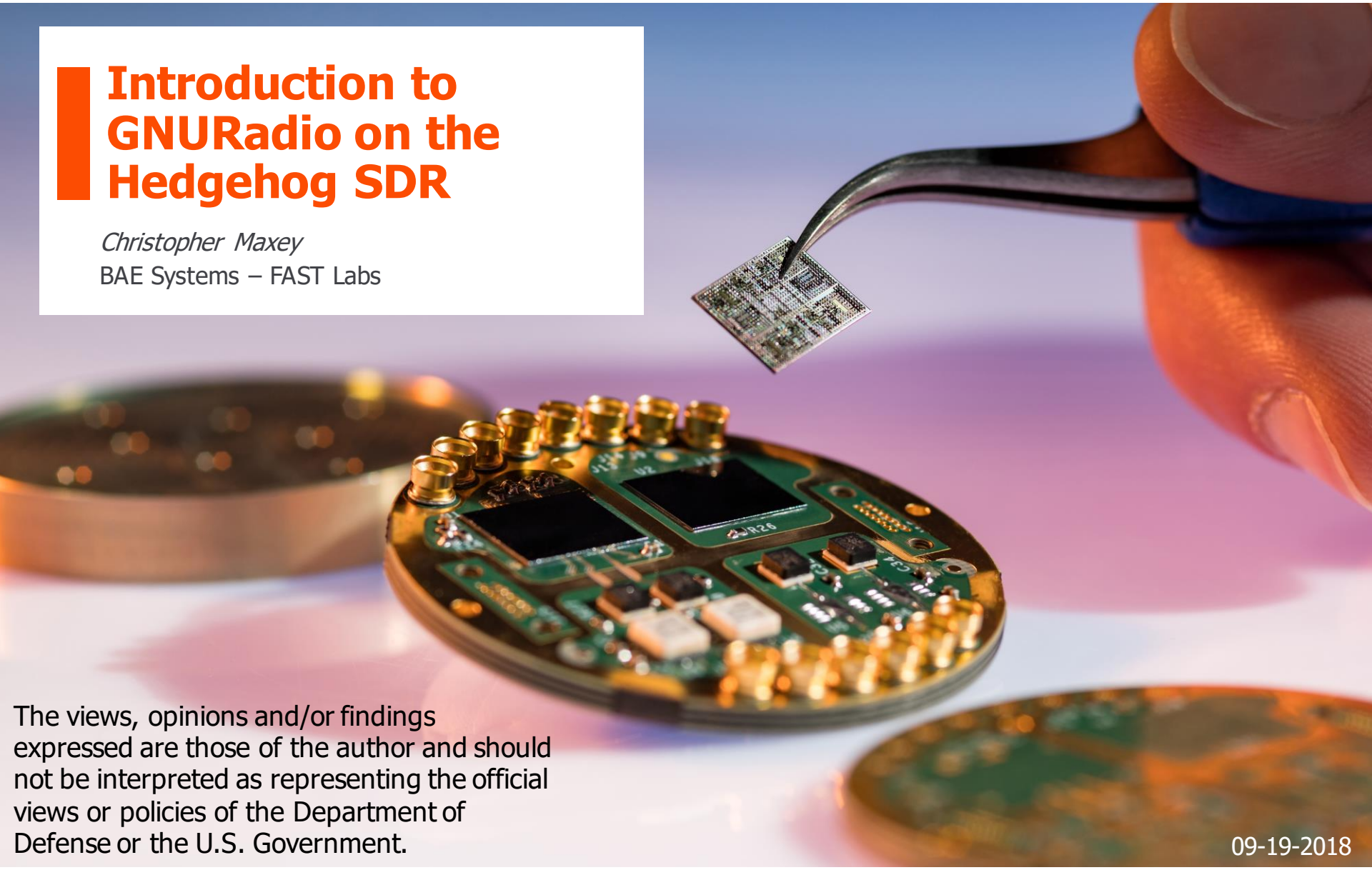
Introduction to GNURadio on the Hedgehog SDR

Christopher Maxey
BAE Systems – FAST Labs



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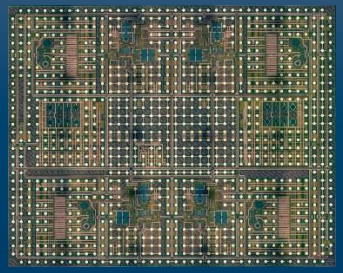
09-19-2018

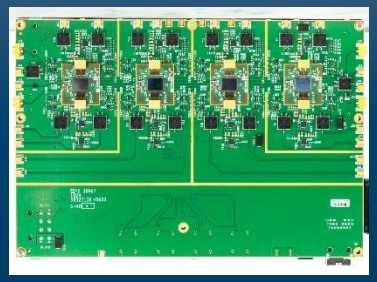
Agenda

Intro

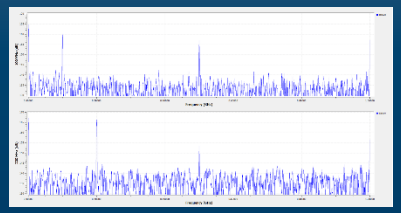
MATRICs RF-FPGA



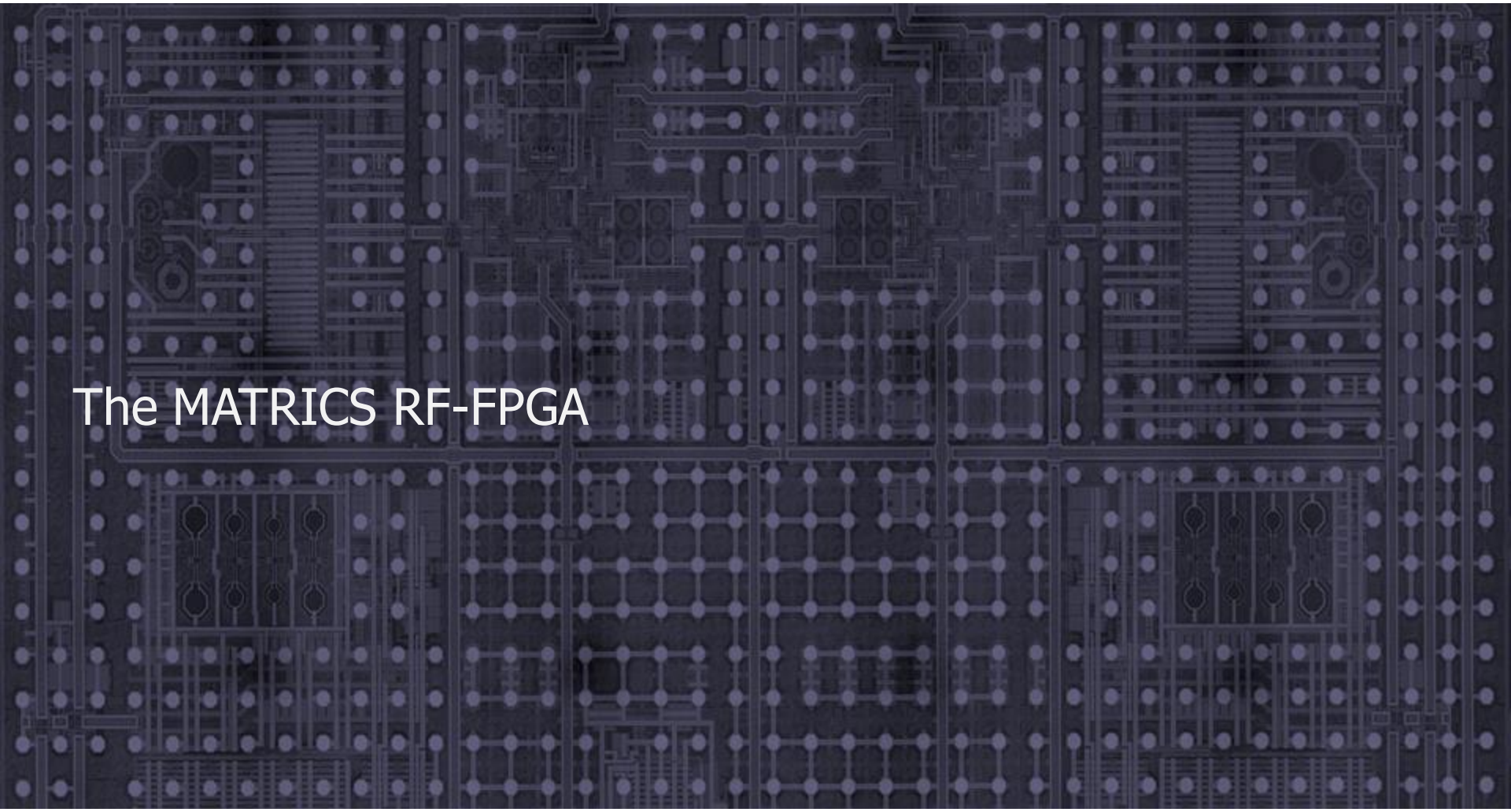
Hedgehog Module



GnuRadio on Hedgehog



Wrap-Up



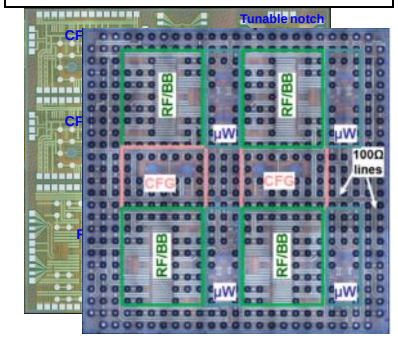
The MATRICS RF-FPGA

Why use a MATRICs RF-FPGA?

- Analogous to Digital FPGA:
  - Save time and money (vs. custom RF ASIC) in low-volume applications
  - **Rapid prototyping**
  - In-field upgrades
  - On-the-fly response to environment

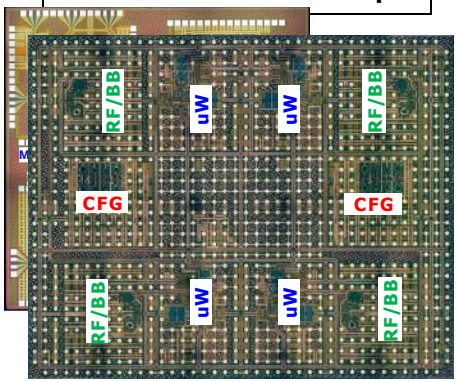
MATRICs RF-FPGA IC progress

MATRICs V1
Tape-out: May 2013
Demo **Full Chip**



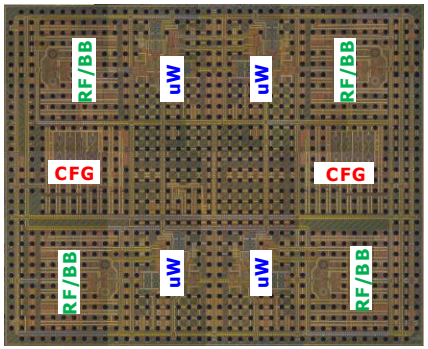
- 1st-generation RF-FPGA
  - 10 functional blocks
  - Microwave switch fabric
  - LO distribution
- Coarse-grained reconfigurability
- DC-to-20 GHz operation
- > 80 dB RF isolation
- Tile-able layout

MATRICs V2
Tape-out: July 2014
Demo **Full Chip**



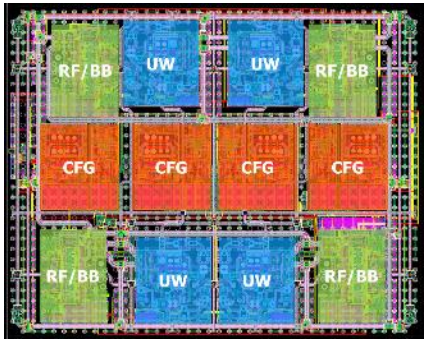
- 2nd-generation RF-FPGA
  - Improved architecture
  - T/R switch
- Lower Phase-noise CFG
- Higher-linearity RF/BB
- Full-functioned MW block
  - Up/down-conversion
  - "MIXORAMP" reconfigurable mixer/amplifier/4-way active switch
- Phase-coherent Fractional-N CFG

MATRICs V3
Tape-out: Jan 2016
Full Chip



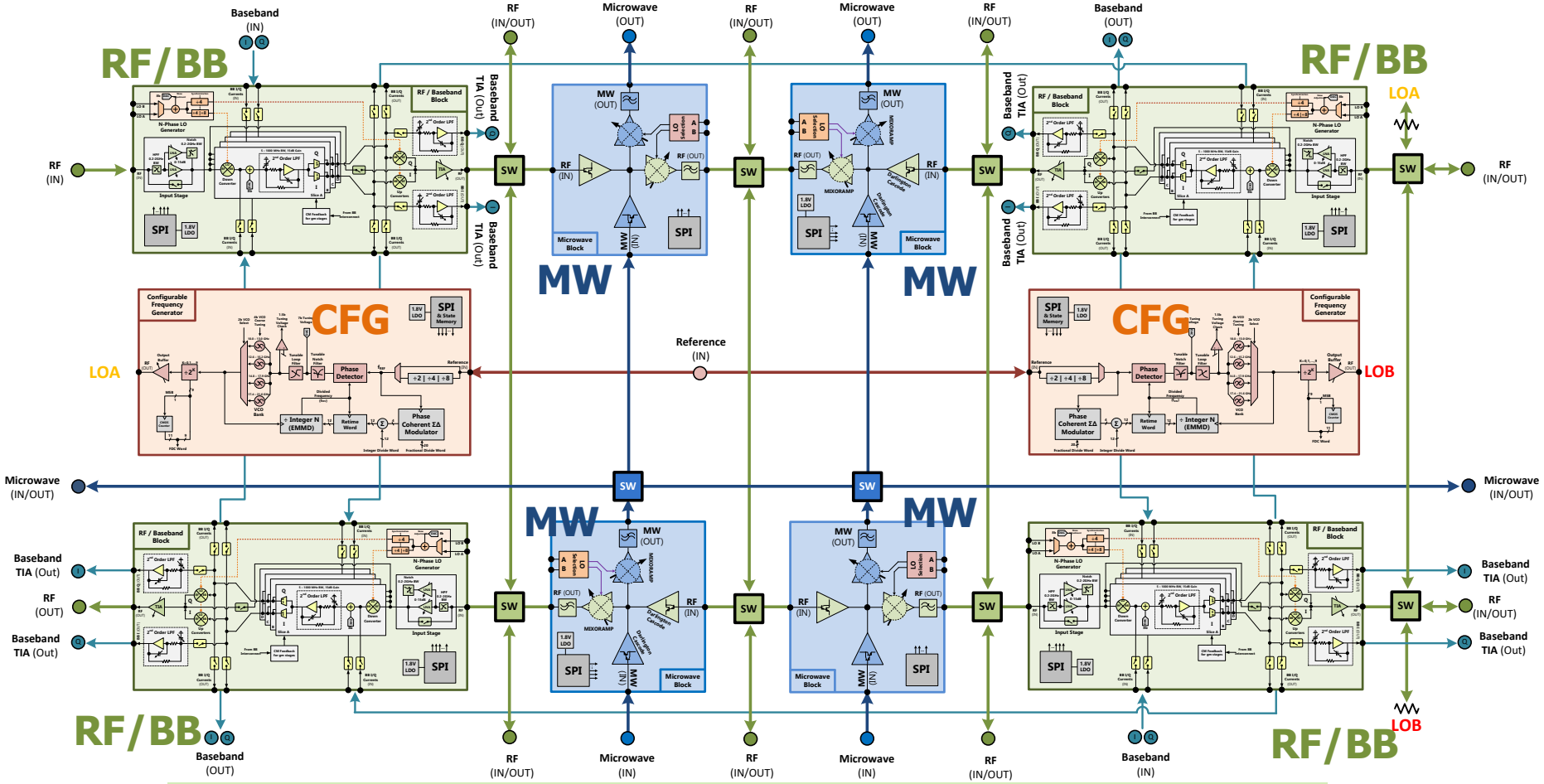
- 3rd-generation RF-FPGA
  - More configurability
  - Improved Performance
- Lower Noise Figure RF/BB
- Reconfigurable Microwave Block
  - Tunable Gain
  - Tunable BW
  - Tunable Dynamic Range
- Improved CFG with lock-detect and calibration circuit
  - VCO overlaps optimized
  - New on-chip VCO calibration algorithm

MATRICs V4
Tape-out: Summer 2018
Full Chip



- 4th-generation RF-FPGA
  - 40 GHz
  - 4 CFGs
  - Improved Performance in new process (SCB13S4B)
- Wider IBW RF/BB Block
  - 4GHz IBW
  - Stretch goal of 10GHz operating frequency
- mmW Microwave Block
  - Extended to 40GHz
- Improved CFGs
  - Extended to 40GHz Support
  - Improved phase noise from new process

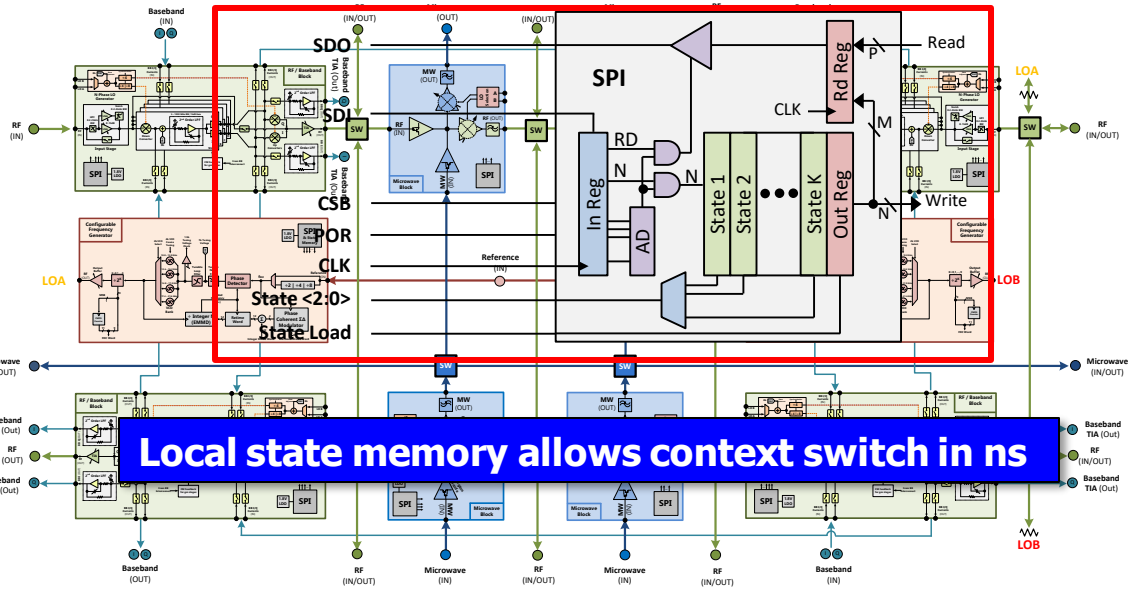
MATRICs V3 architecture



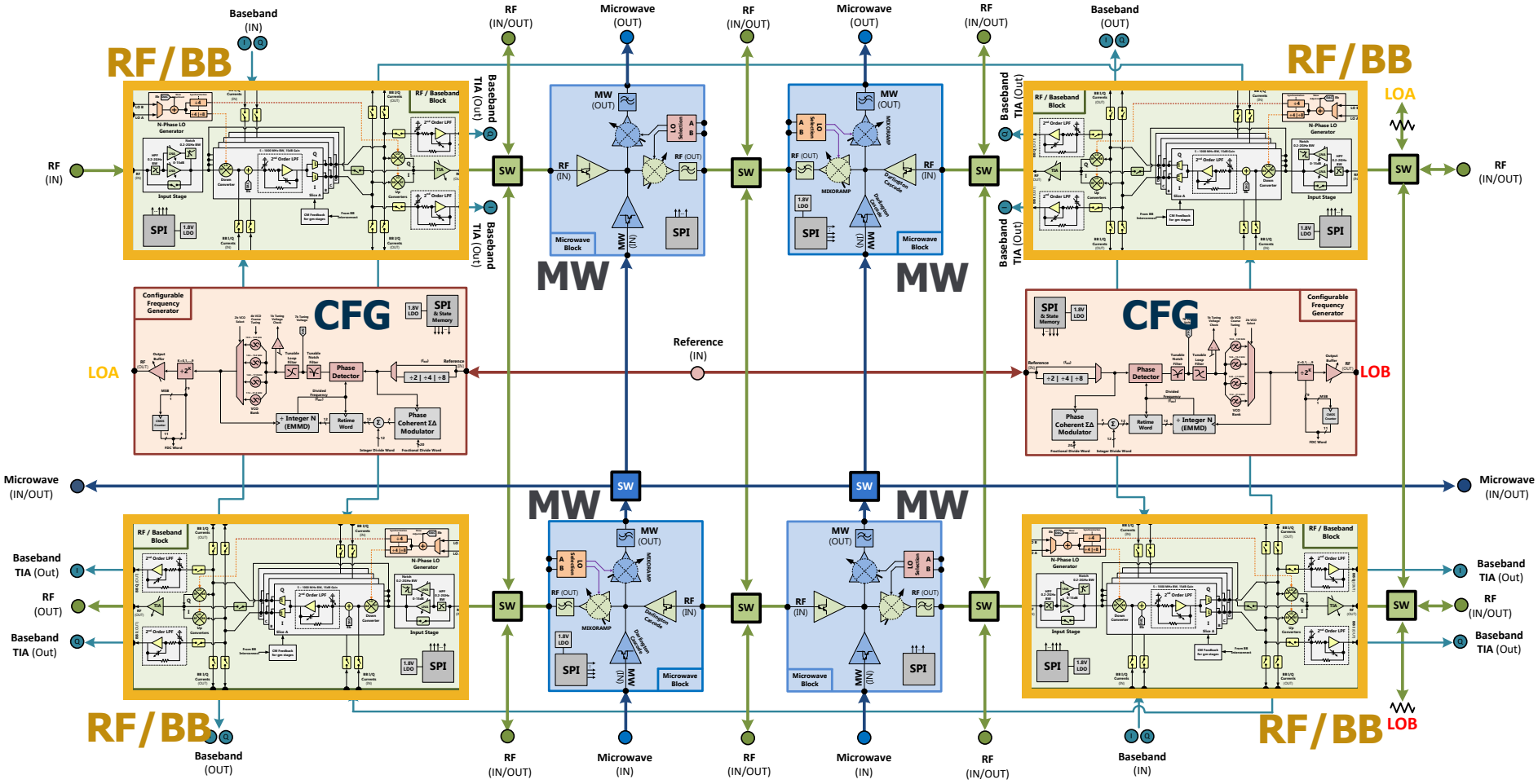
RF/Baseband (RF/BB):	DC to 6 GHz
Microwave (MW):	0.5 GHz to 20 GHz
Configurable Frequency Generator (CFG):	10 MHz to 20 GHz

Highly-reconfigurable two-tier hybrid architecture

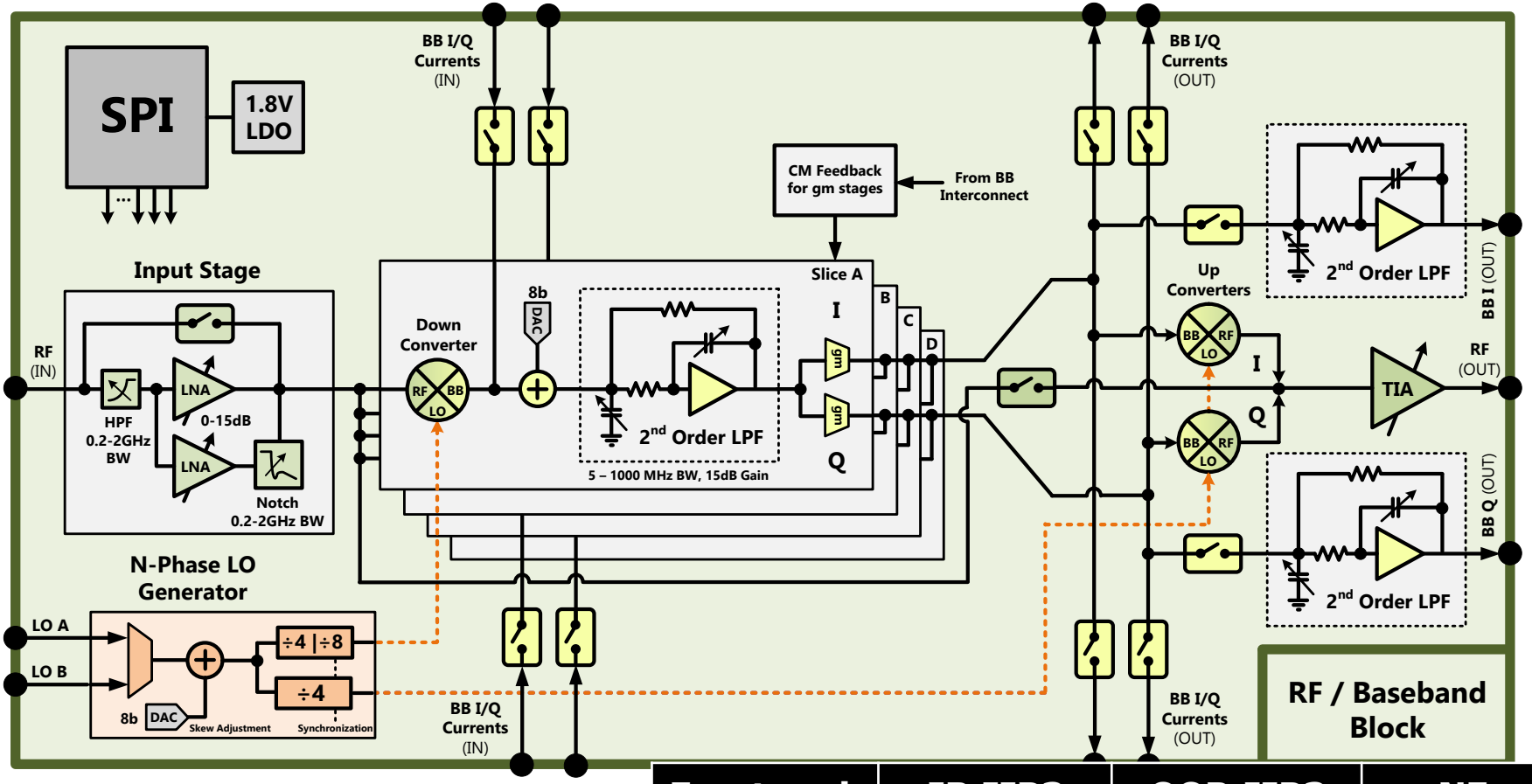
- Coarse-grained outer switch fabric/ fine-grained switching internal to blocks
  - Reconfigurable architecture:
    - Direct Conversion Rx
    - Superheterodyne Rx
    - I/Q upconverter
    - RF Transceiver
    - Microwave MUX/ DEMUX
  - Reconfigurable blocks:
    - IBW: 10MHz to 2 GHz
    - Gain: 0 to 40dB/ block
    - Linearity vs. DC power
    - Center frequency: 10 MHz to 20 GHz
    - Integer-N and Fractional-N PLL with on-chip programmable loop filter
- Distributed SPI & State Memory (~1kbits) for dynamic reconfiguration in ns



RF/Baseband Block (RF/BB): DC-to-6 GHz



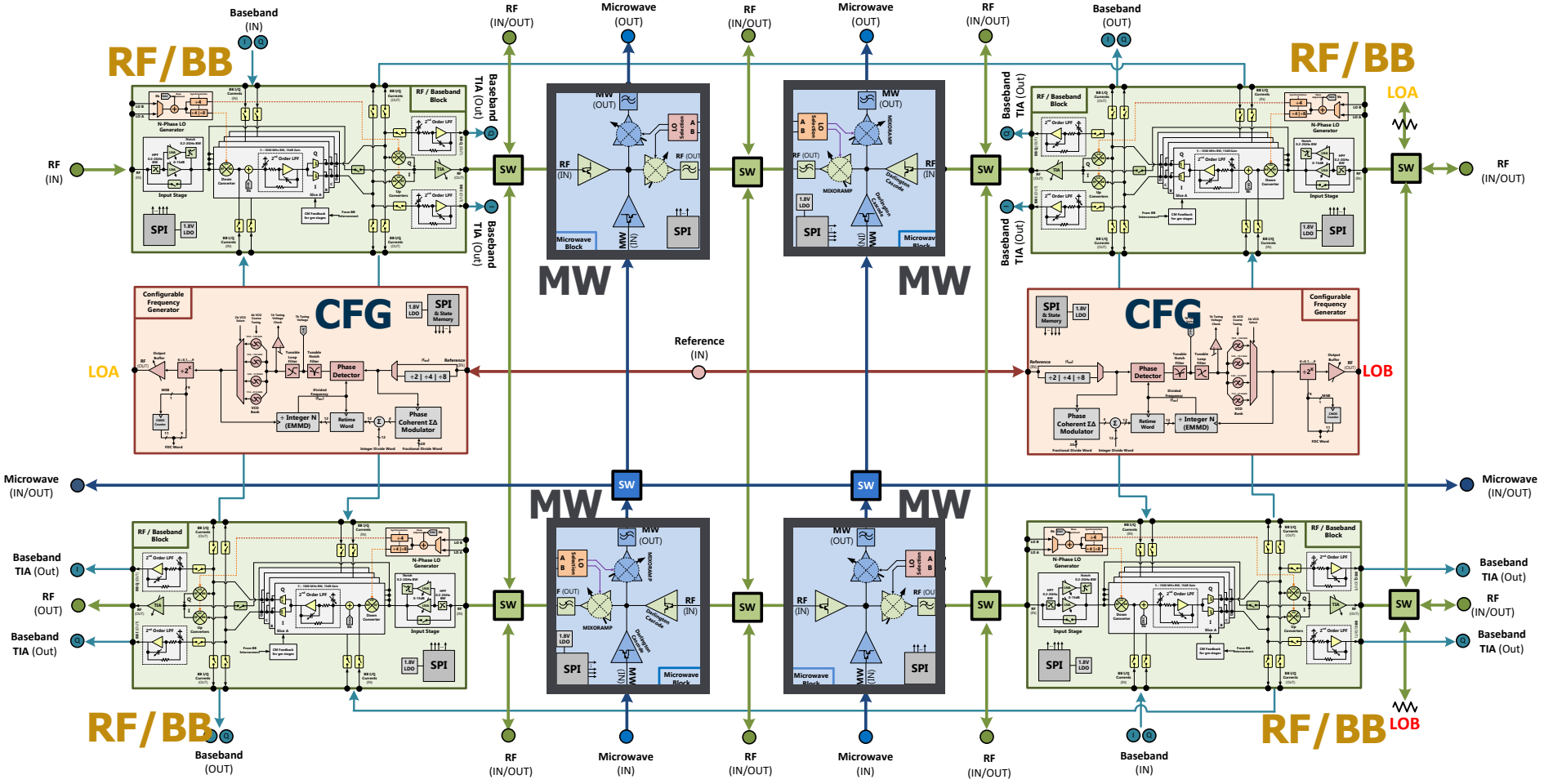
RF/Baseband Block (RF/BB): DC-to-6 GHz



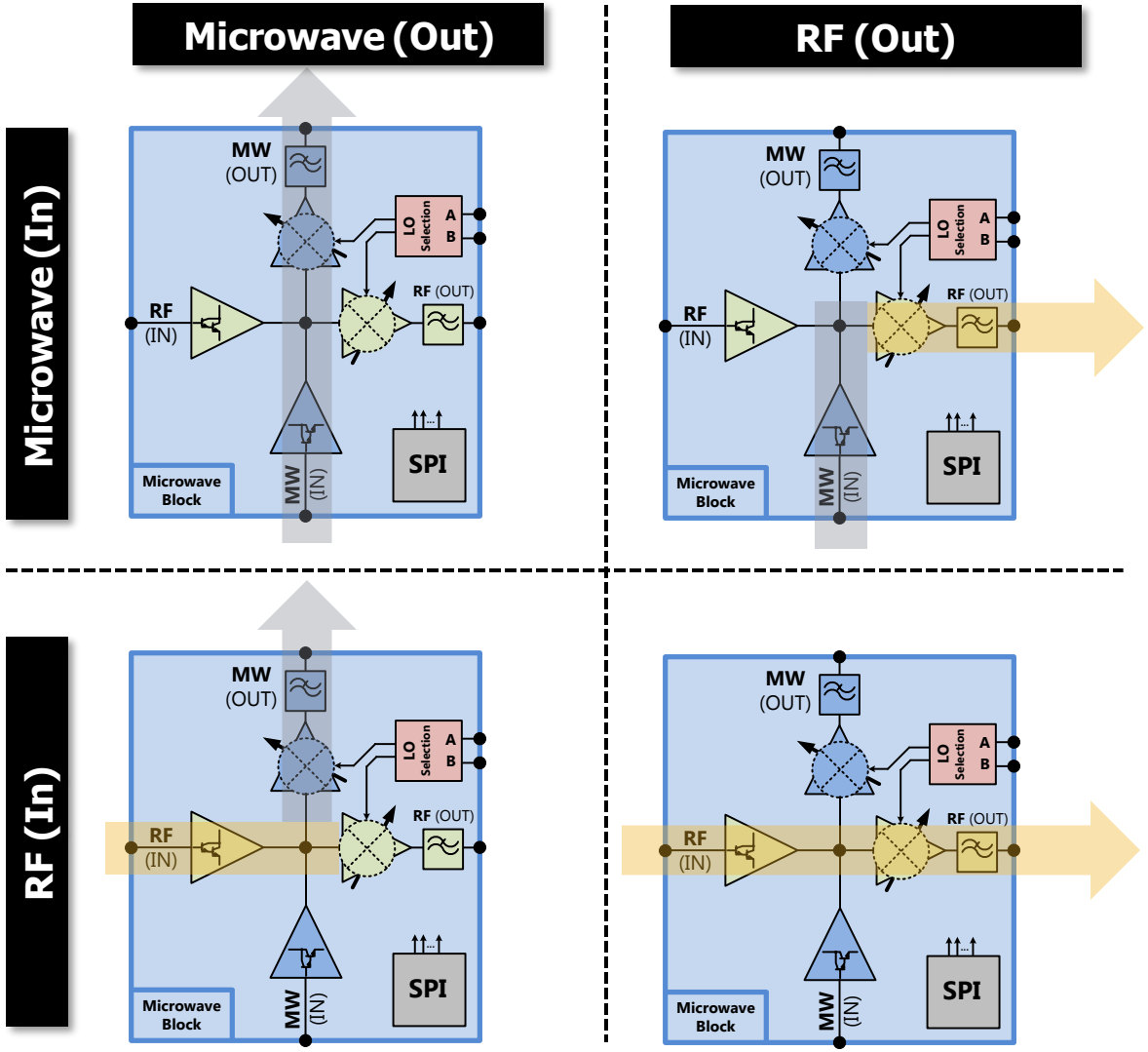
- 4- and 8-path direct-conversion Rx
- I/Q upconverter

Front-end	IB IIP3	OOB IIP3	NF
LNA-1st	> +5 dBm	> +12 dBm	< 10 dB
Mixer-1st	> +15 dBm	> +30 dBm	< 14 dB

Microwave Block (MW): 0.5 to 20 GHz



Microwave block usage



- Amplification
- Frequency conversion
- Signal routing

RF: DC to 6 GHz

MW: 0.5 to 20 GHz

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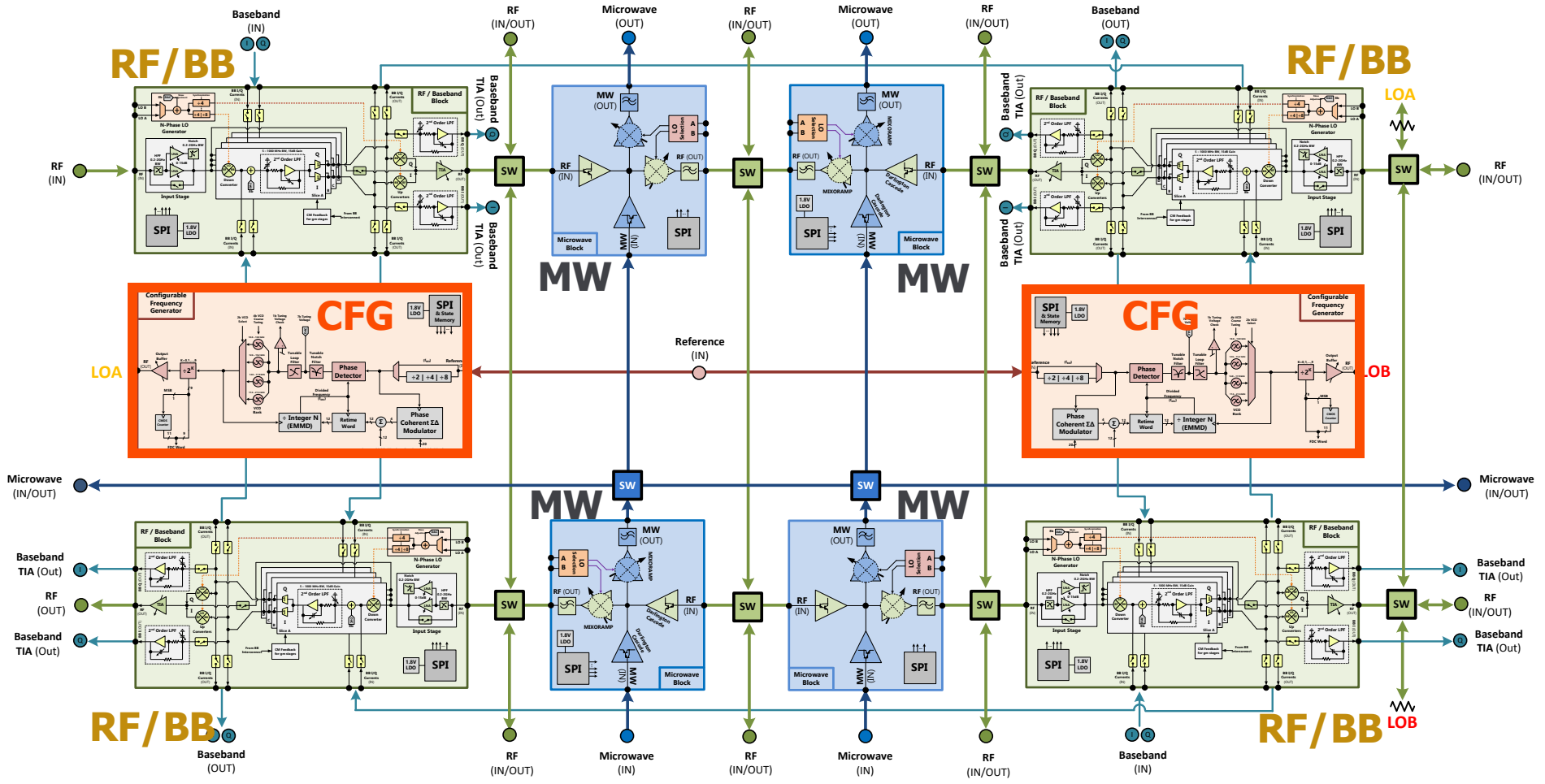
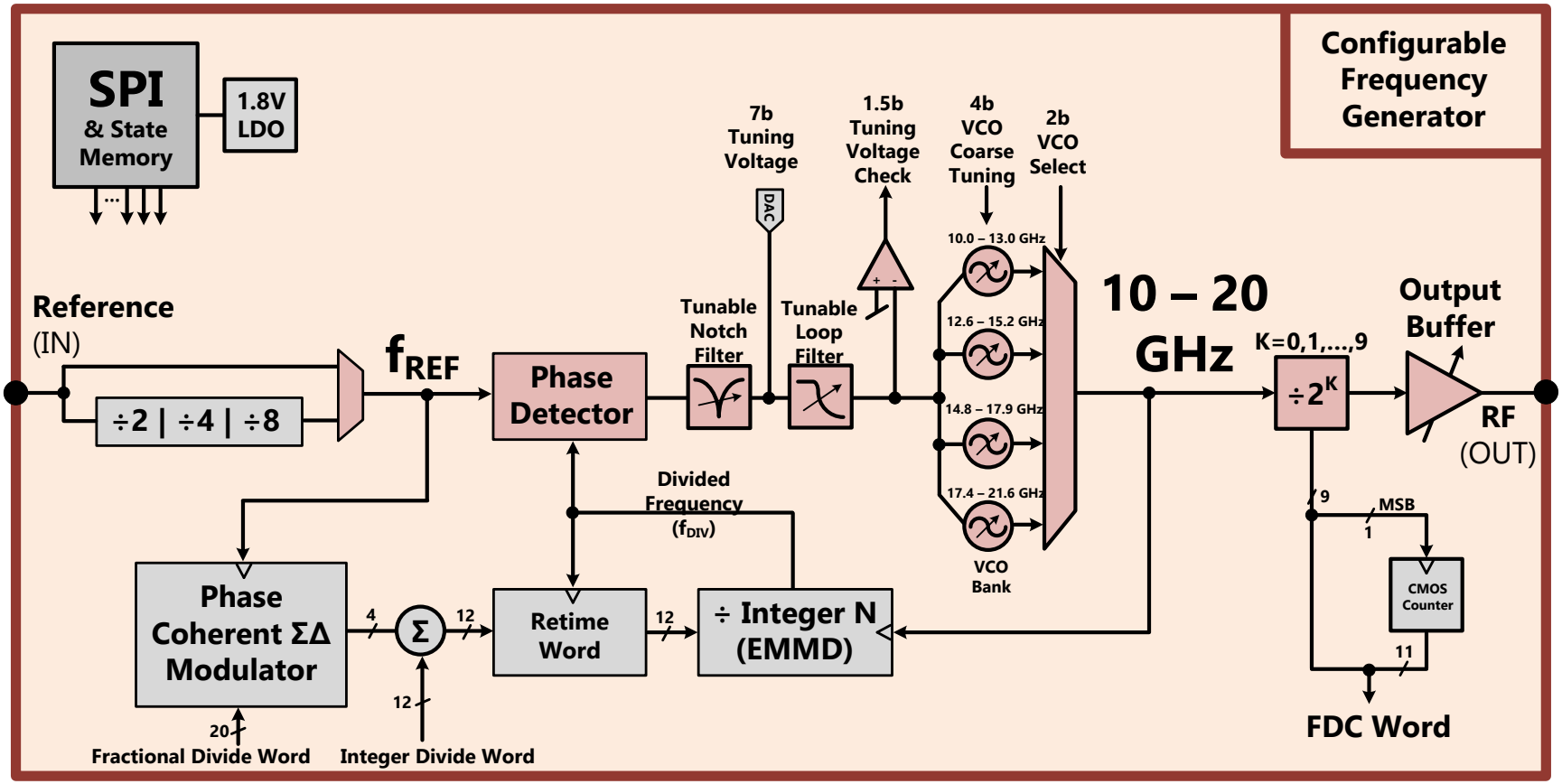
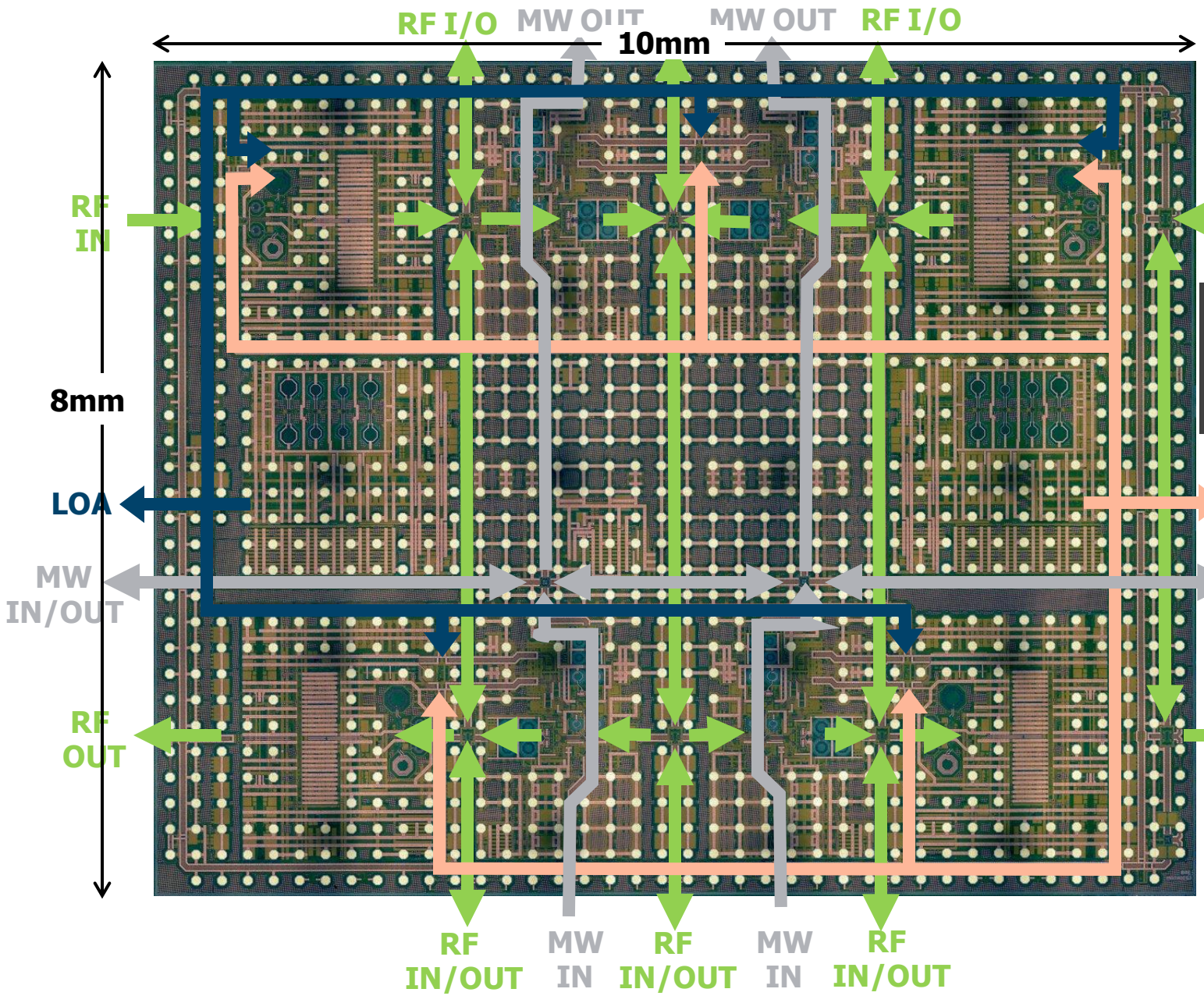
Configurable Frequency Generator (CFG)



MATRICs V3 Configurable Frequency Generator (CFG)



- Integer-N and ΣΔ fractional-N modes
- Octave-BW PLL (10 to 20 GHz) followed by binary divider
- Quad SiGe VCOs, each with 16 coarse-tuning sub-bands



- Jazz SBC18H3B SiGe-on-SOI CMOS
- Flip-chip bump mounting

MW: 0.5 - 20 GHz

RF: DC- 6 GHz

LO: 10 MHz – 20 GHz

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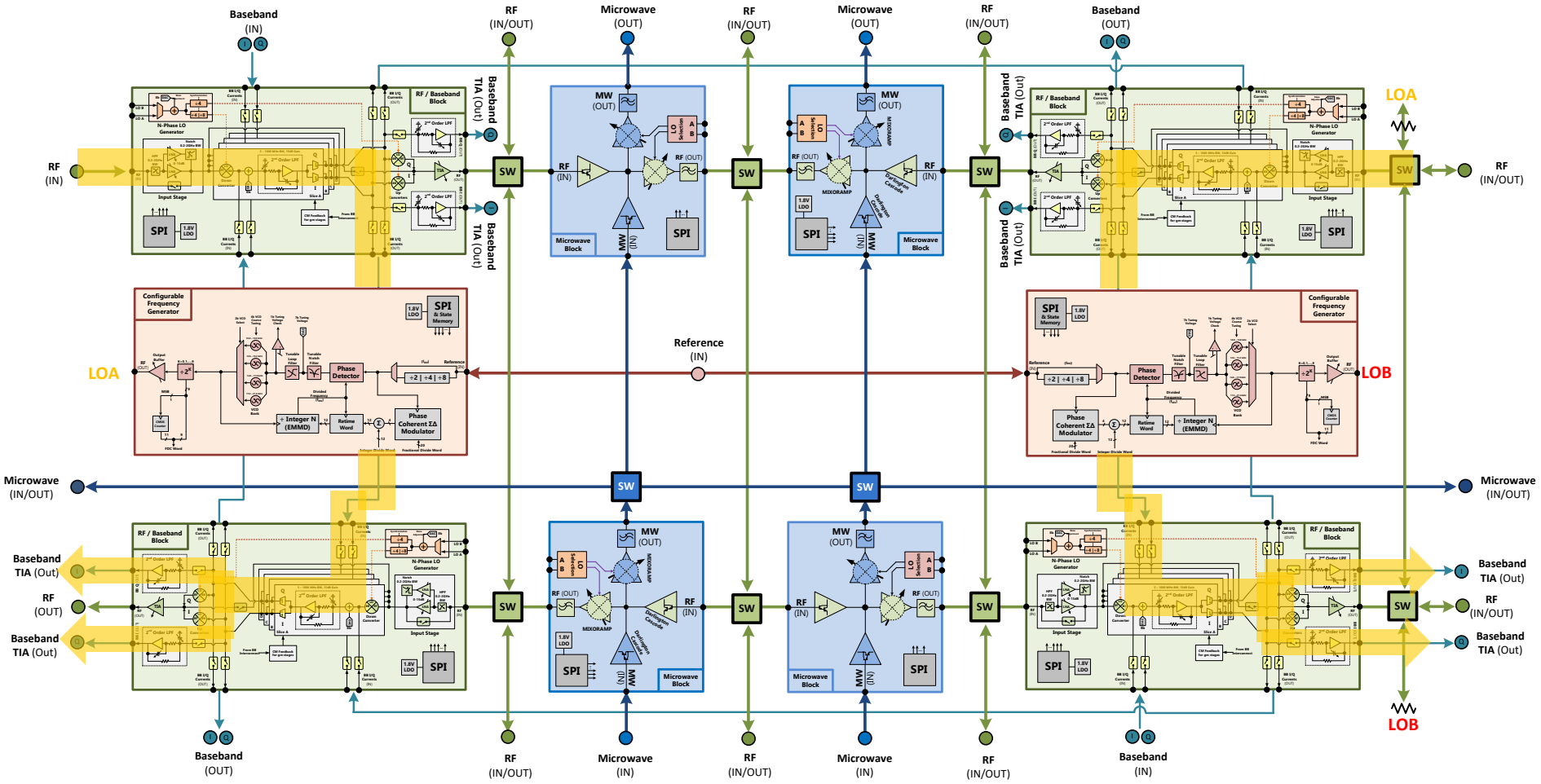
2-channel DC-to-6 GHz direct conversion Rx



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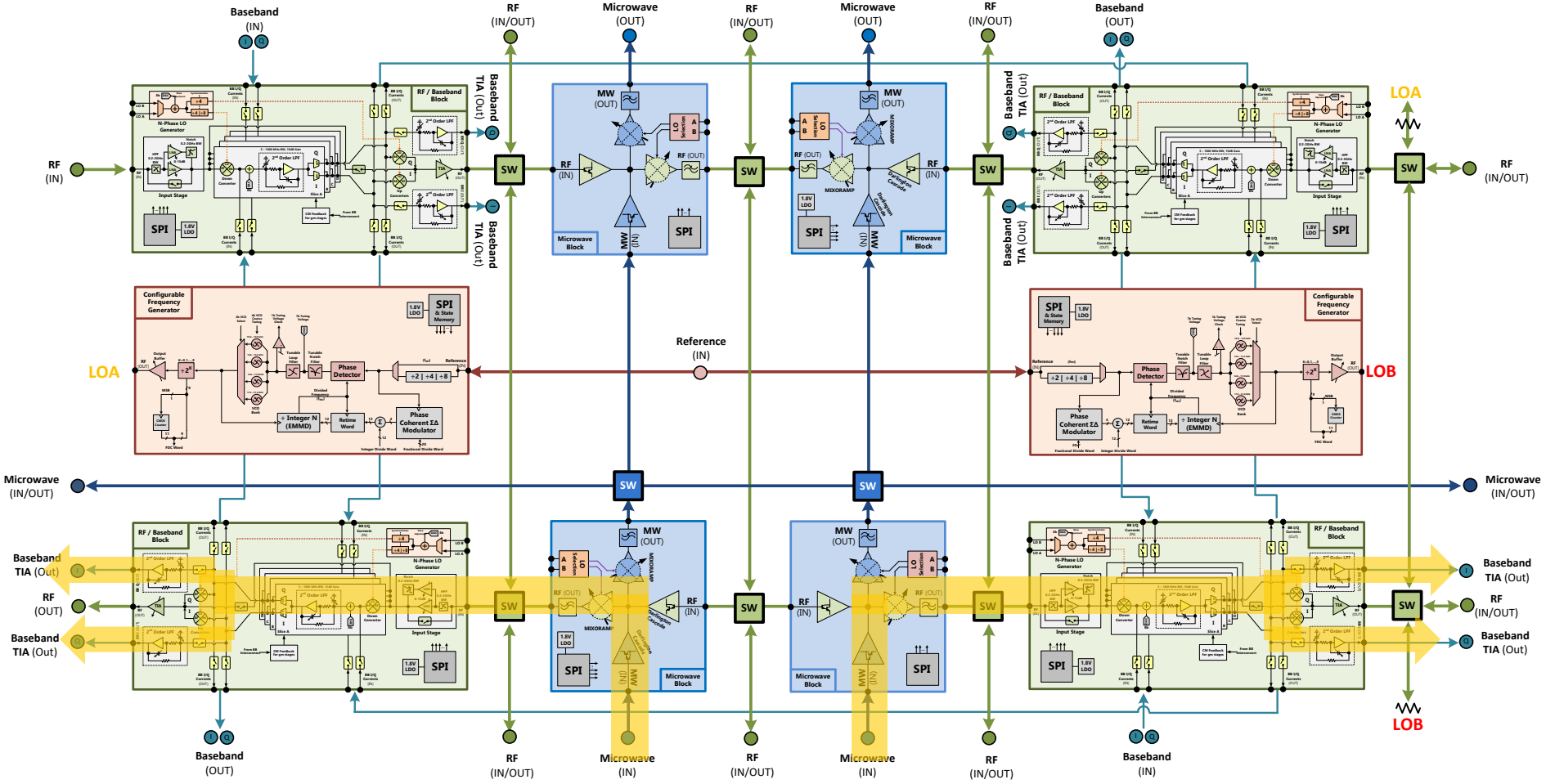
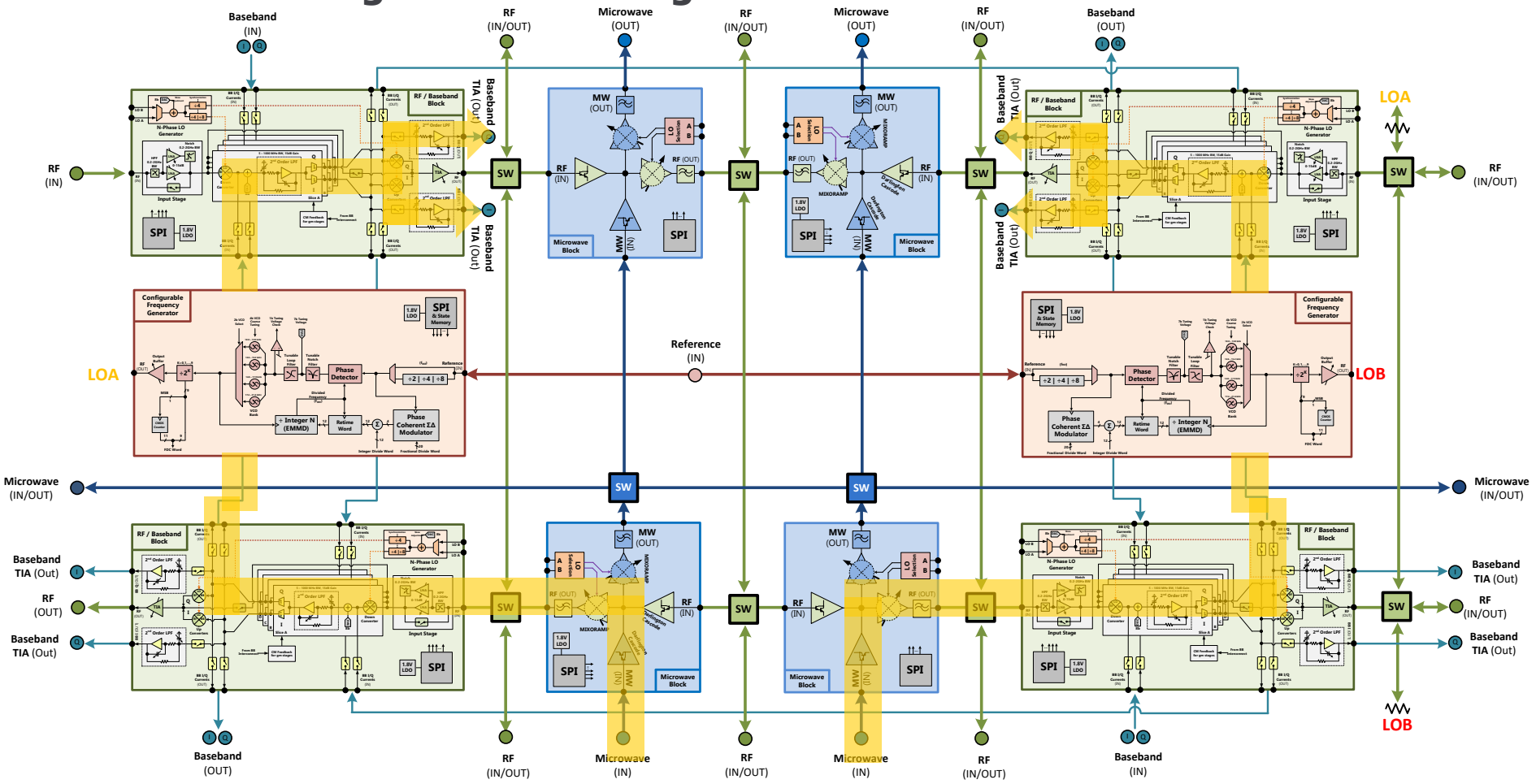
2-channel 0.5-to-20 GHz super-heterodyne Rx

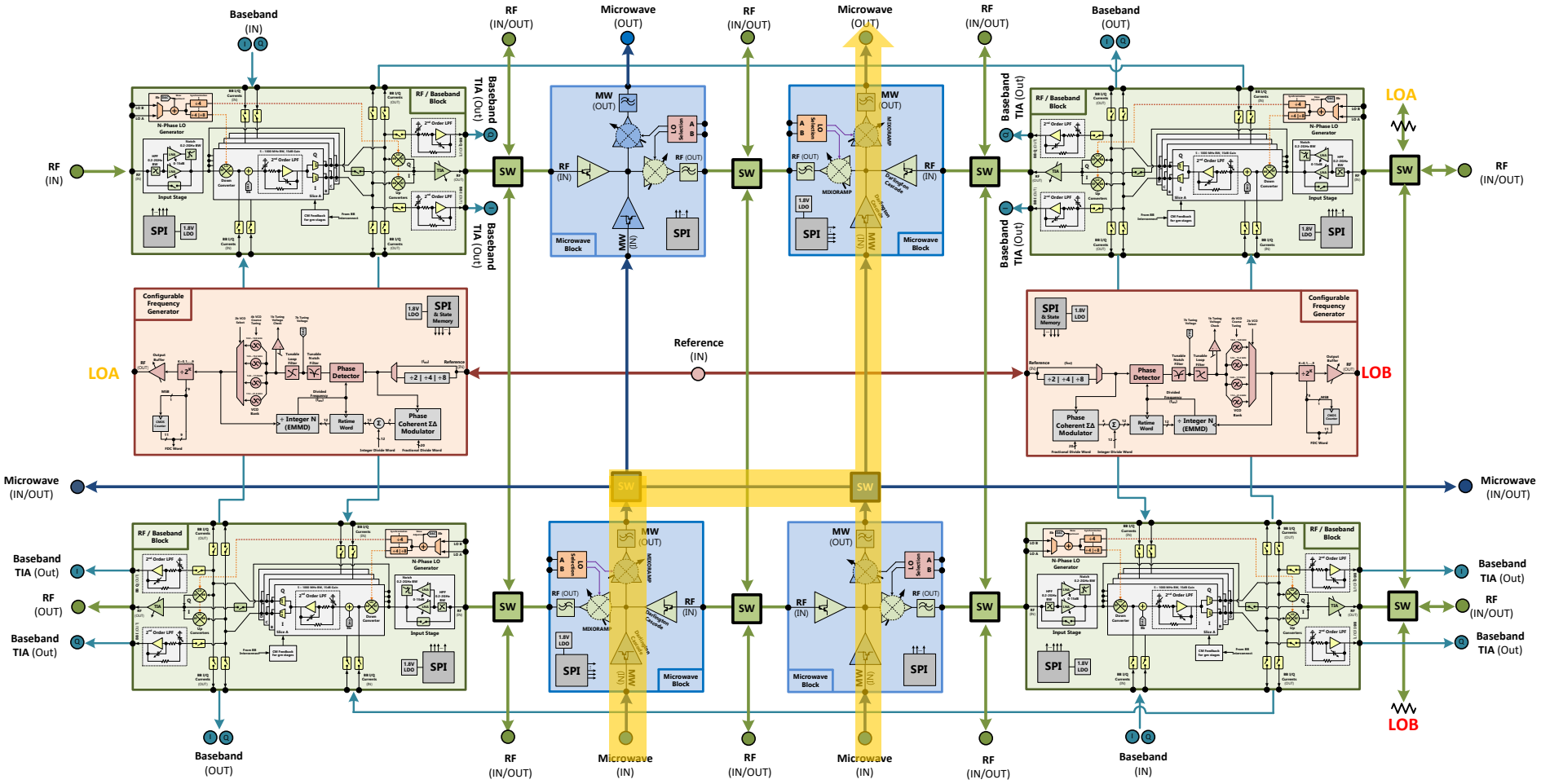


2-channel 0.5-to-20 GHz super-heterodyne Rx

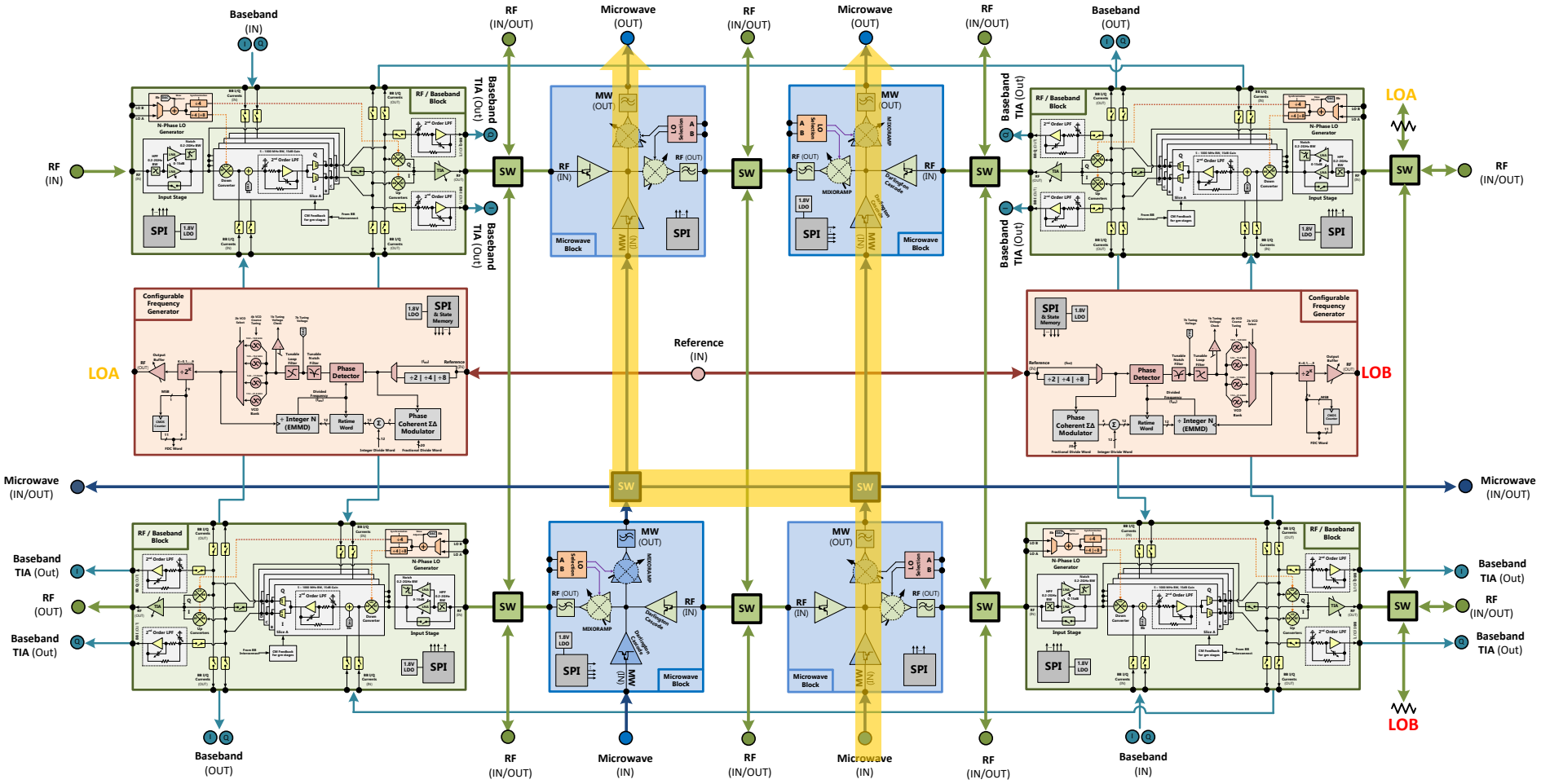
with increased gain and filtering



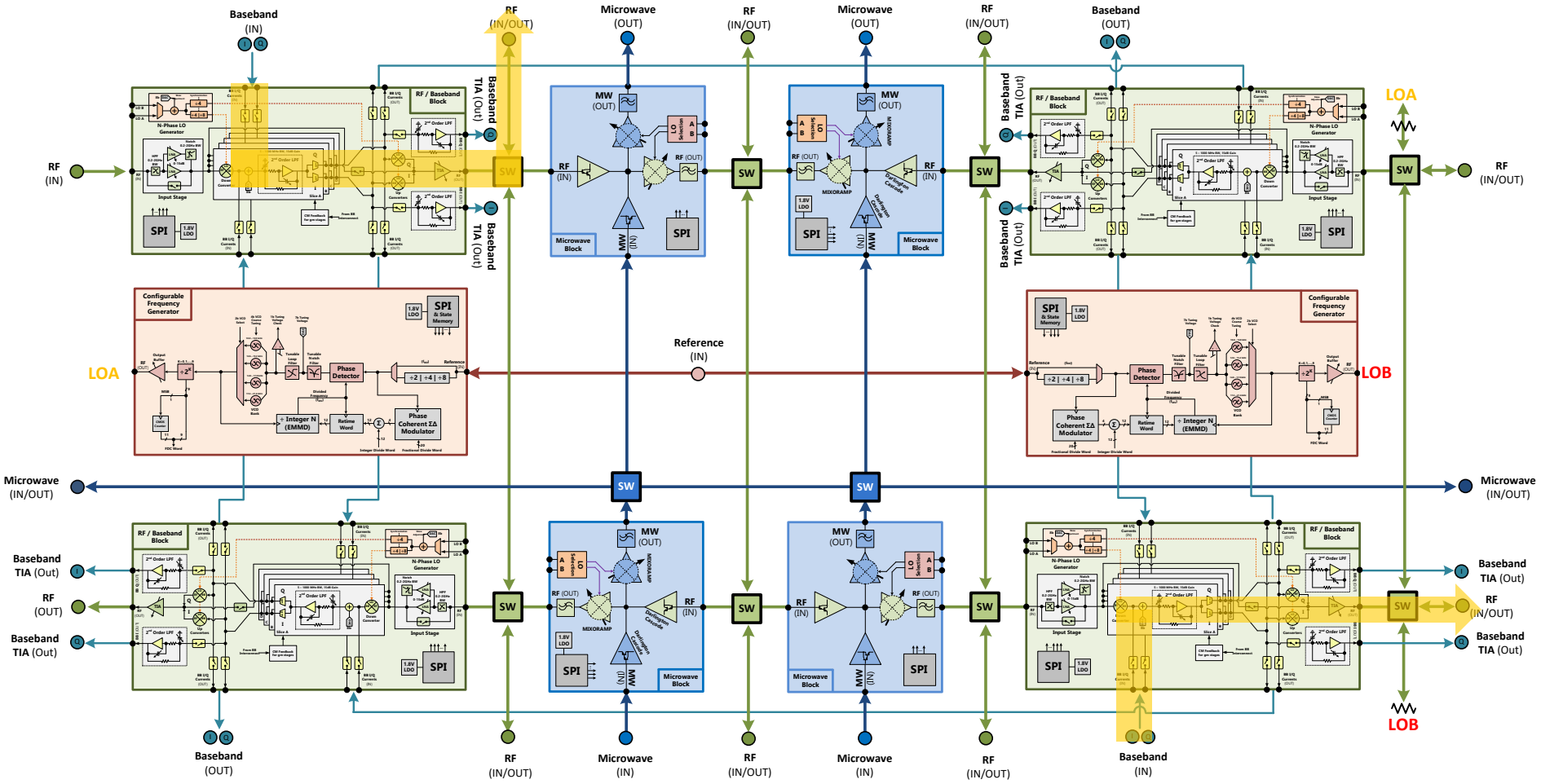
2:1 microwave MUX/ amplifier / down-/up-converter



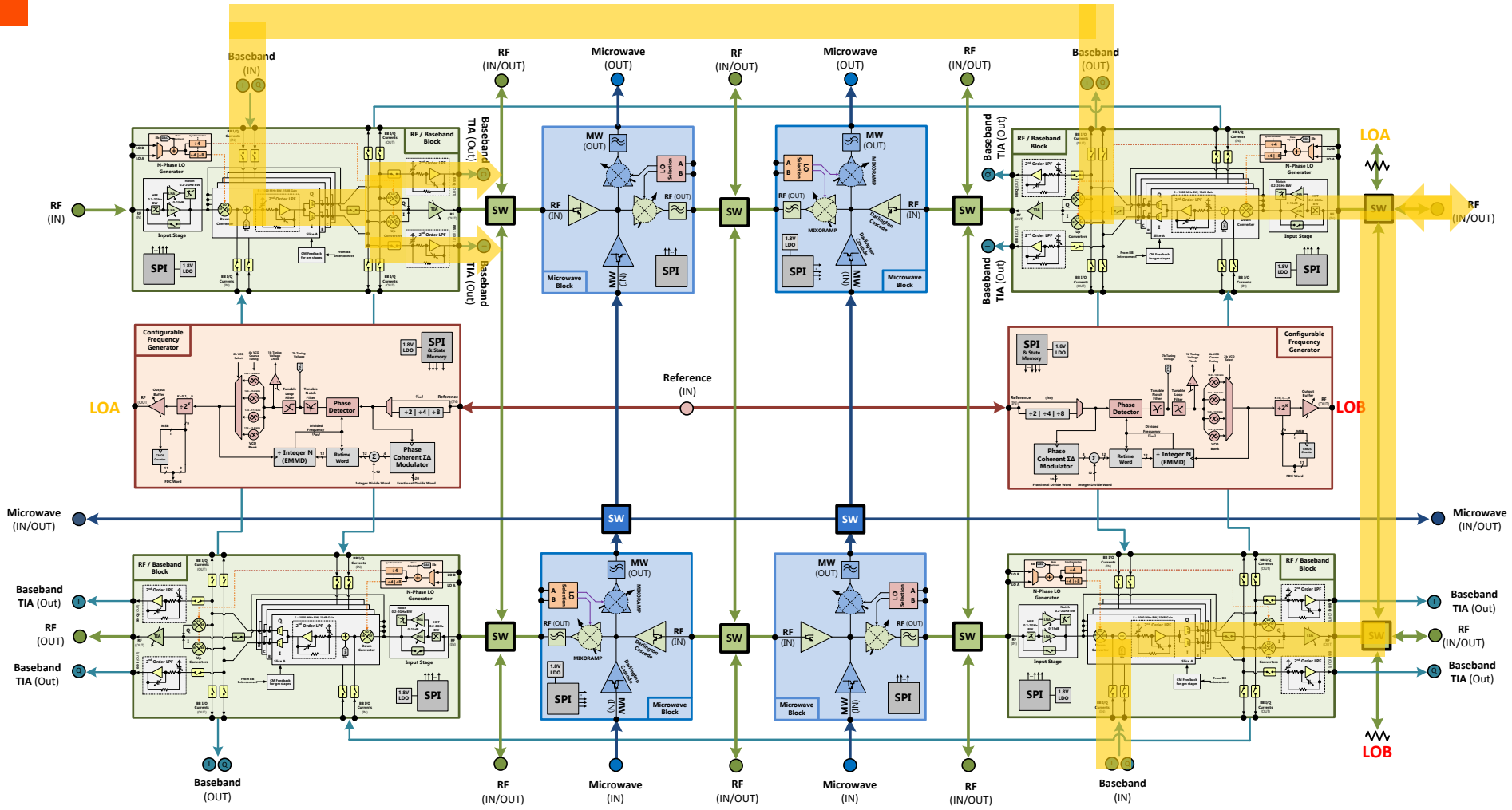
Microwave amplifier / down-/up-converter / 1:2 router



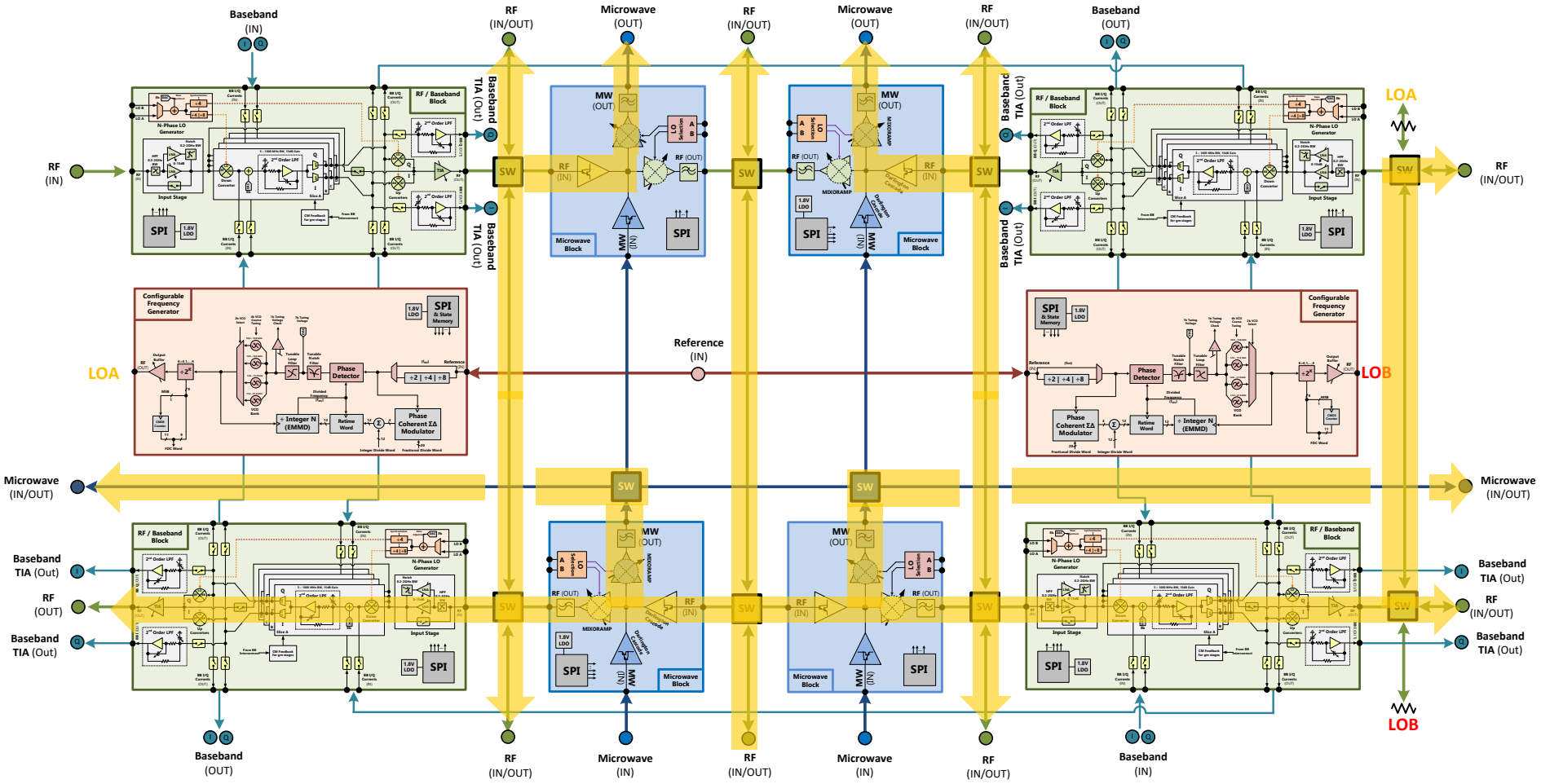
Dual I/Q up-converters



DC-to-6 GHz RF transceiver



1:12 DC-to-6 GHz RF signal router



Distribution Statement "A" (Approved for Public Release, Distribution Unlimited). If you have any questions, please contact the Public Release Center.

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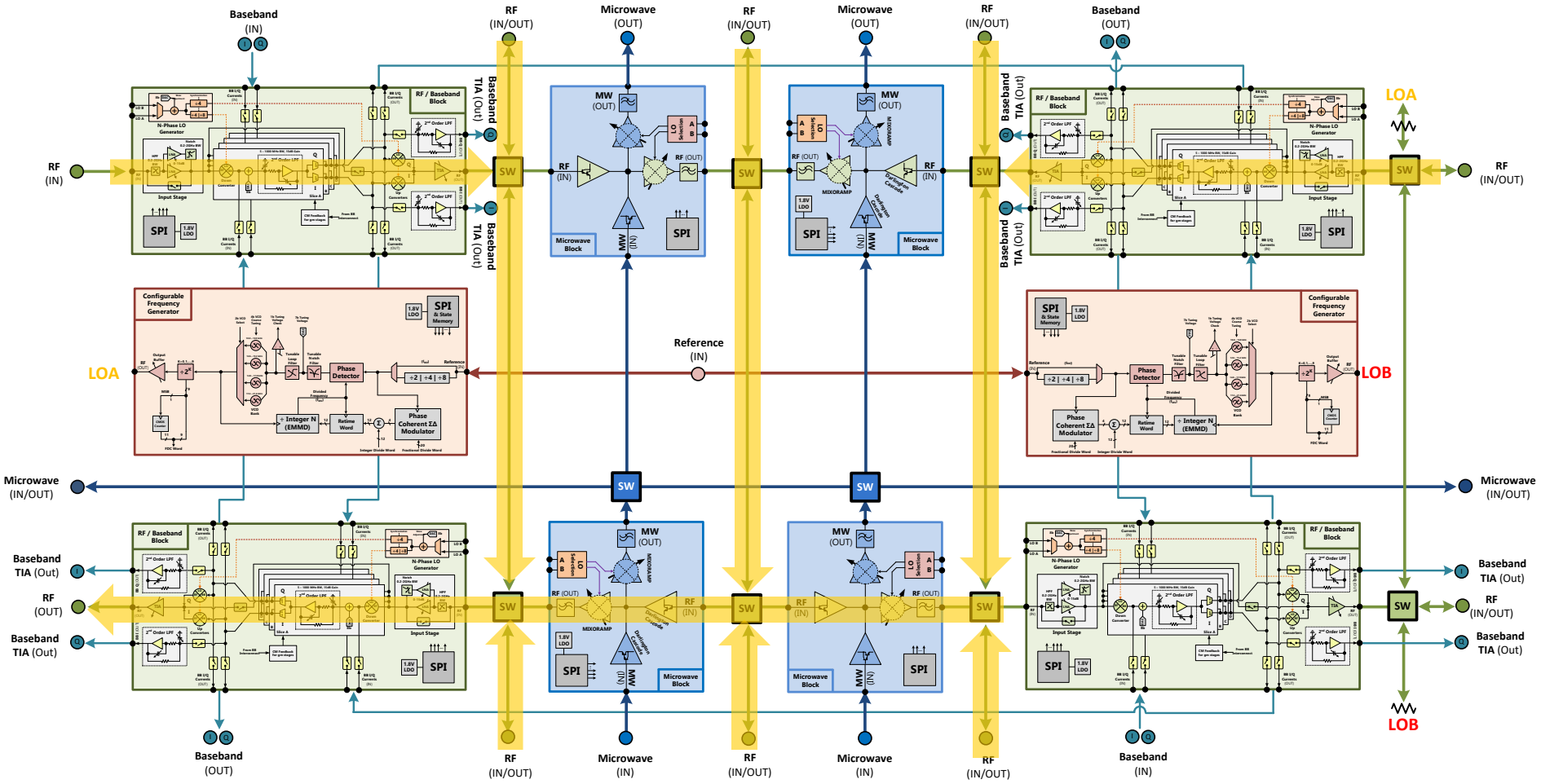
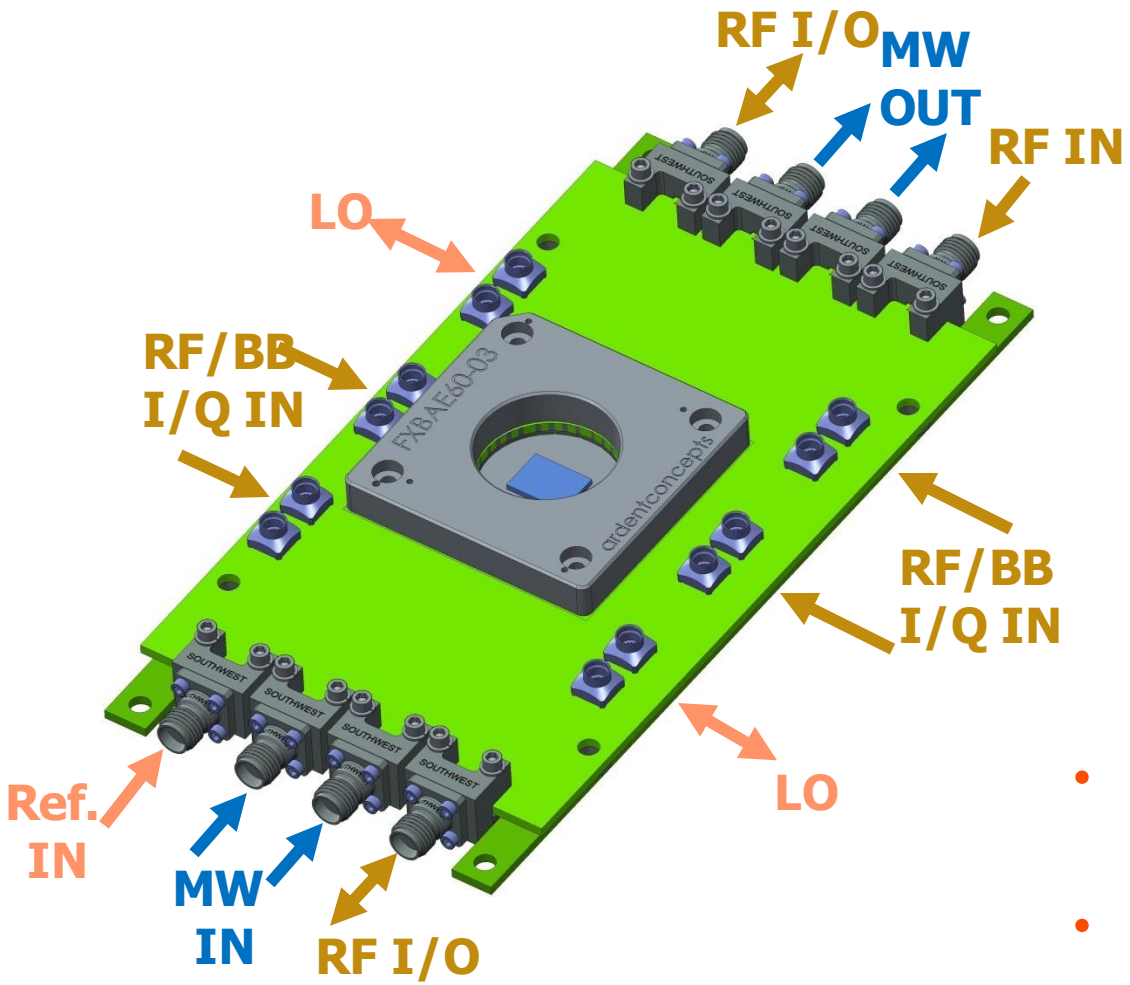
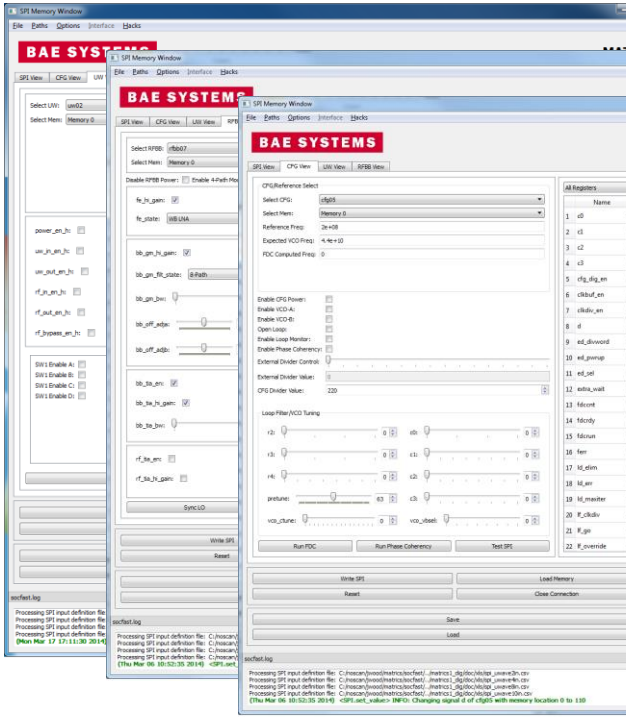
8:1 DC-to-6 GHz RF MUX



MATRICs Evaluation Board (top view)

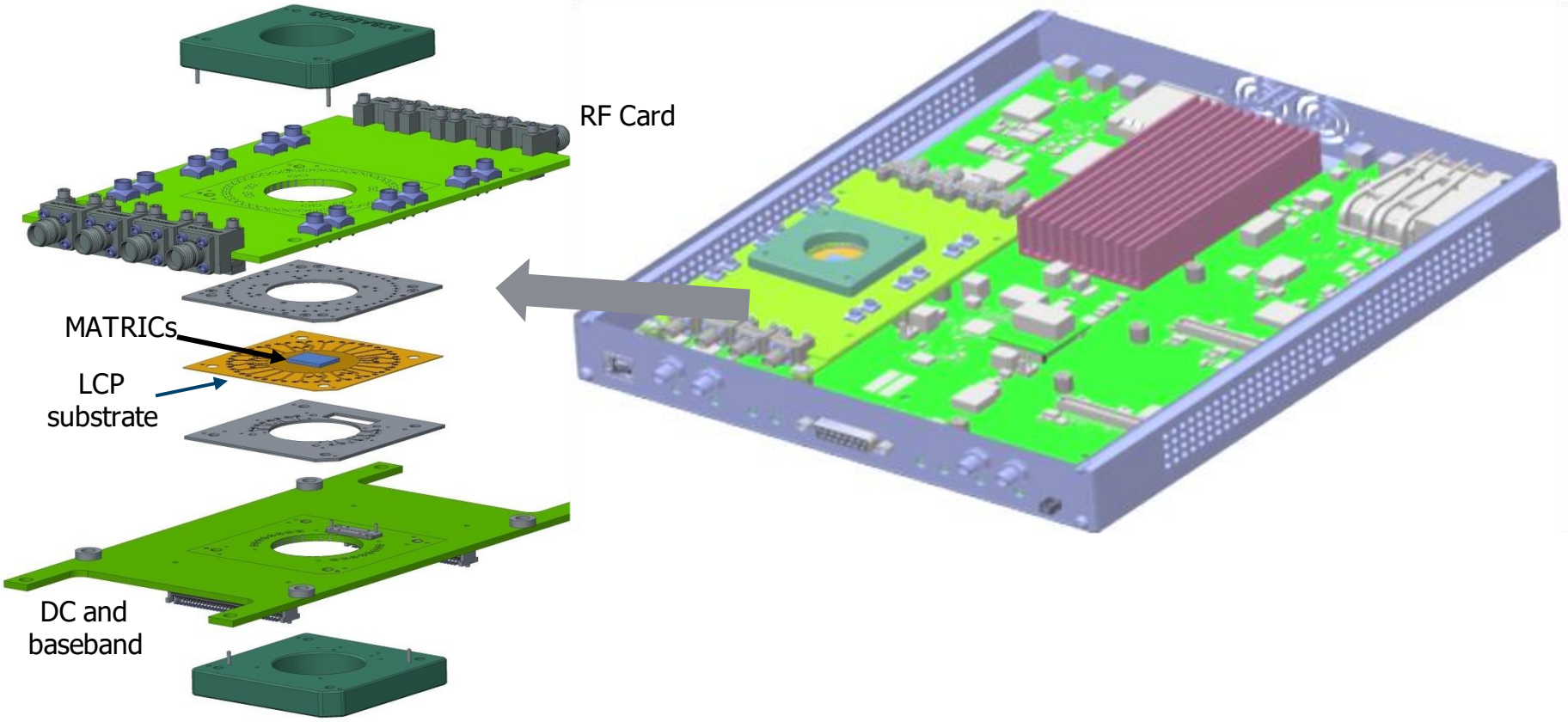




GUIs for µW , RF/BB, & CFG Configuration

- High-isolation socket holds MATRICs IC on LCP substrate
- On-board broadband baluns

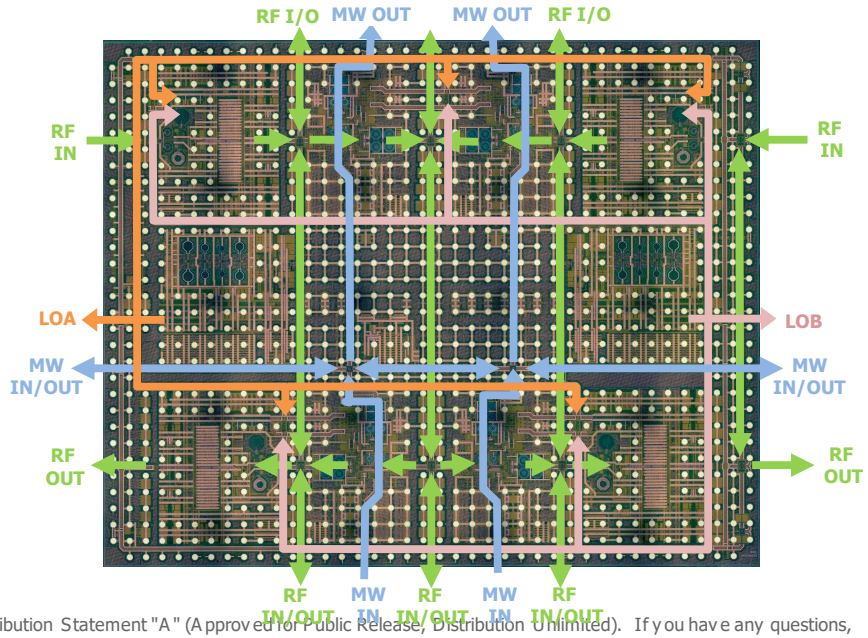
Ettus X310 / NI USRP-294x SDR compatibility



Leverage NI/Ettus SDR hardware (ADCs, DACs, FPGAs, and power supplies) and open-source software

MATRICs RF-FPGA Summary

- Save time and $$ vs. custom RF ASIC development
- Enables rapid reconfiguration and on-the-fly adaptation
  - Rapid prototyping
  - In-field upgrades
  - Dynamic frequency planning
  - Performance on demand
- Ettus-compatible evaluation board available



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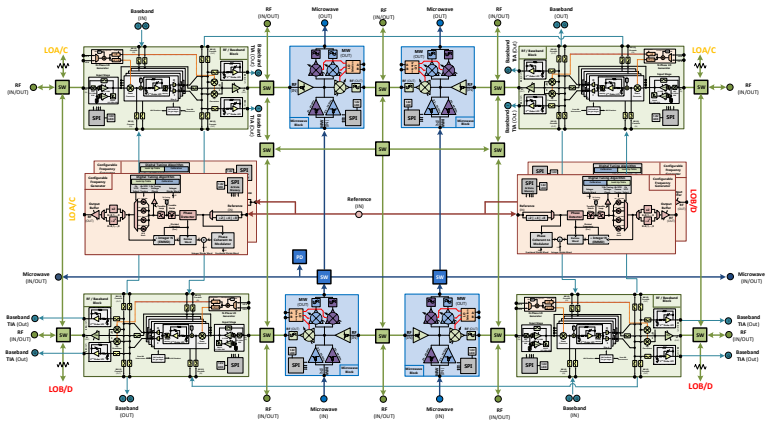
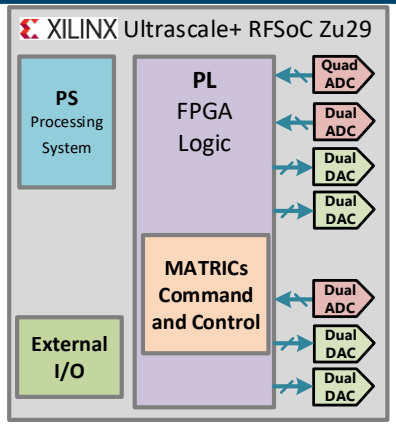
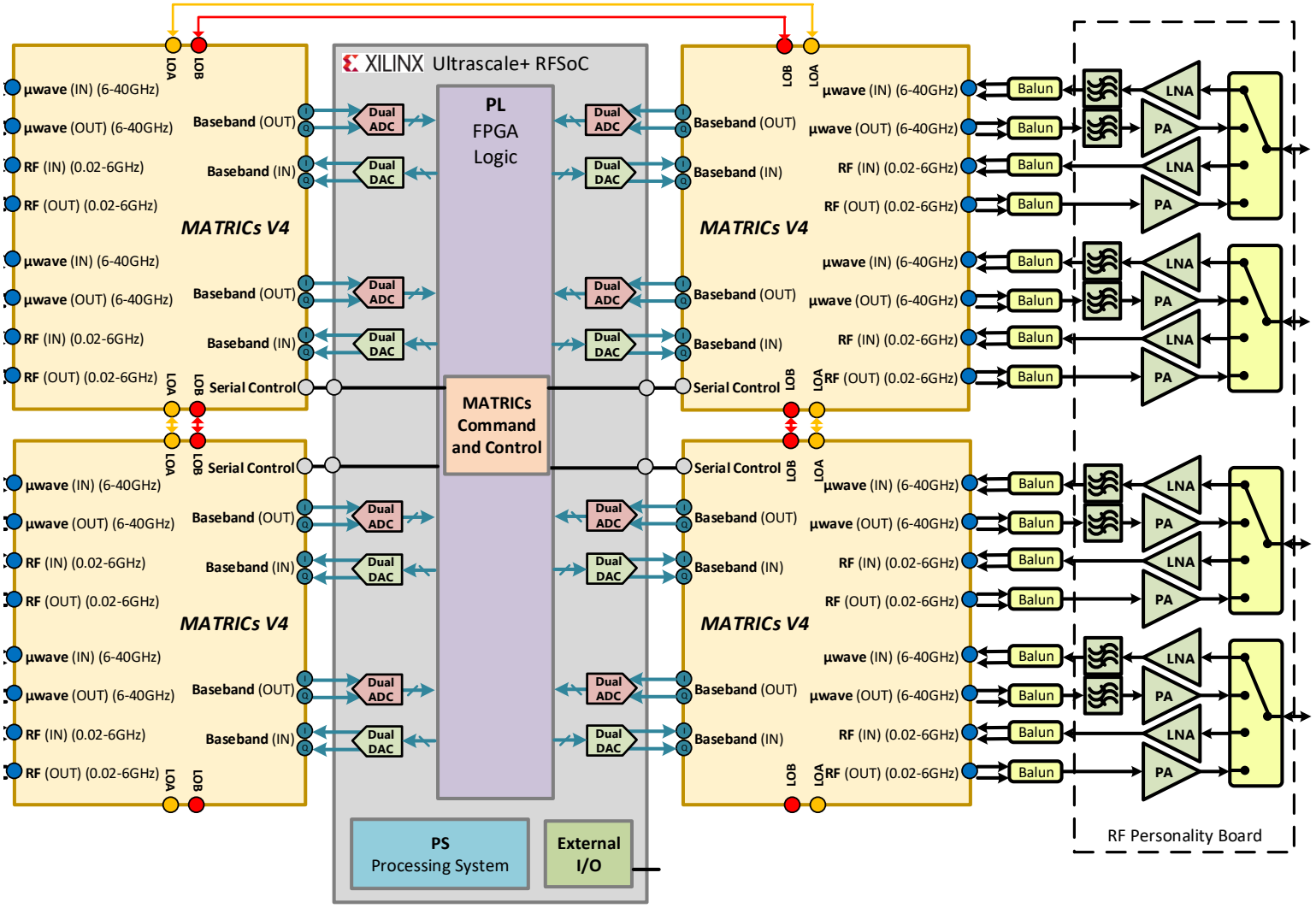
The Hedgehog Module

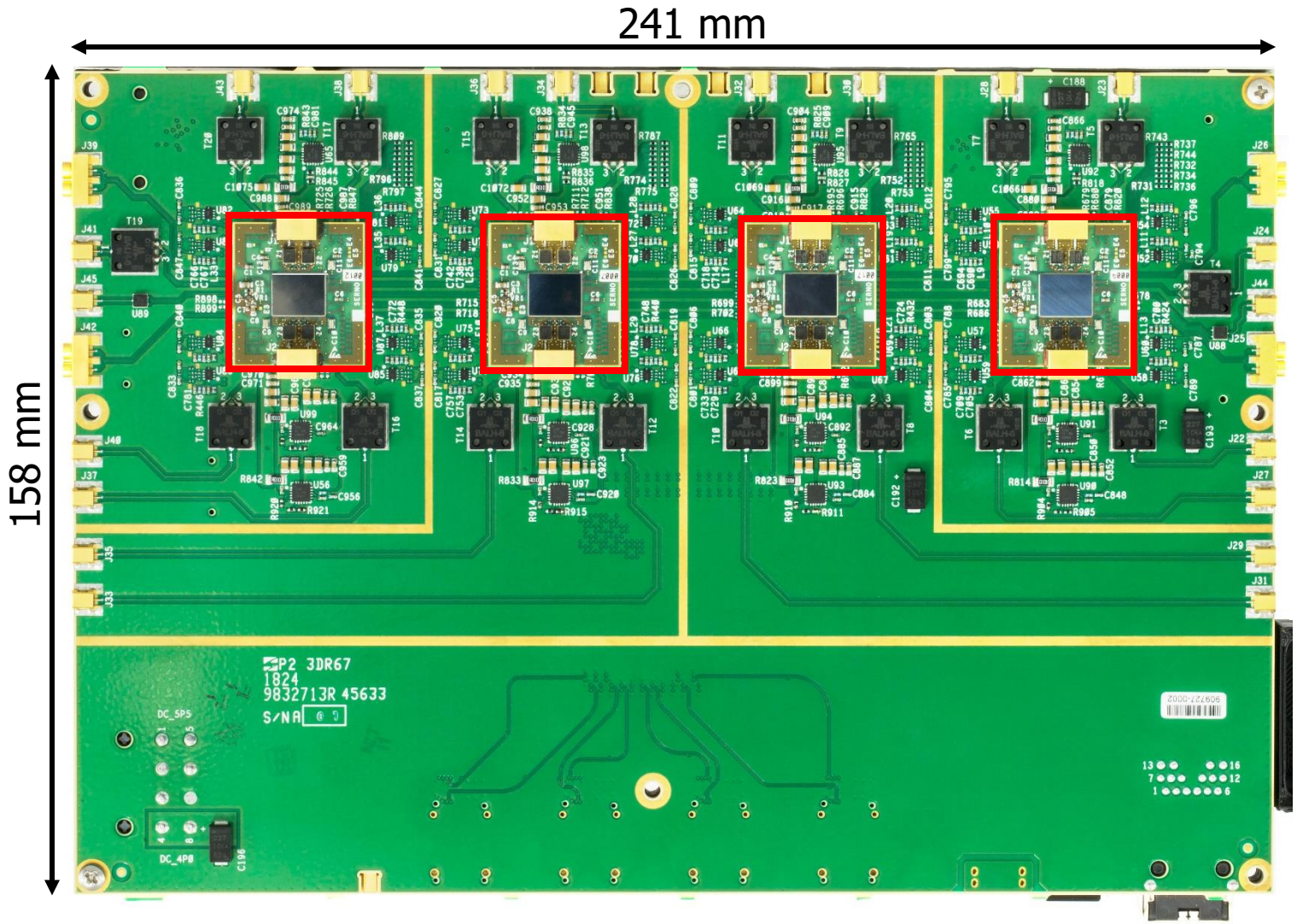
Two transcendent RF SoCs

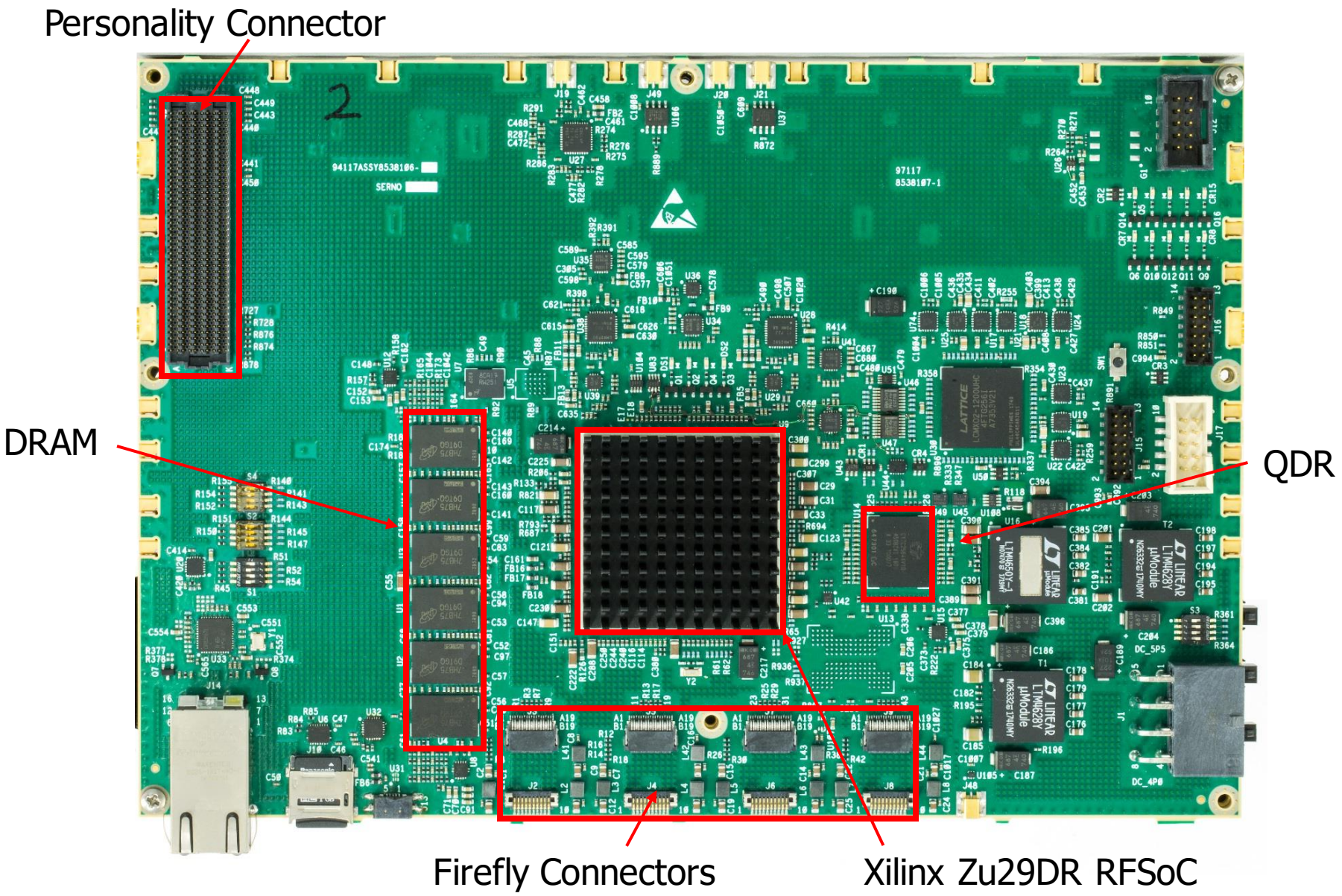
MATRICs V4	Ultrascale+ RFSoC
	
World's first mm-wave multi-function monolithic transceiver	World's first integrated multi-processor, multi-converter FPGA
Arbitrarily switchable fabric made possible by 130 nm BiCMOS-on-SOI	Eliminates JESD204B/C analog interface, dramatically saving power and latency
82% component count reduction compared to discrete implementations	
High channel density for scalable, integrated array applications	
Integrated software/firmware for rapid development of custom radios	

Hedgehog Block Diagram

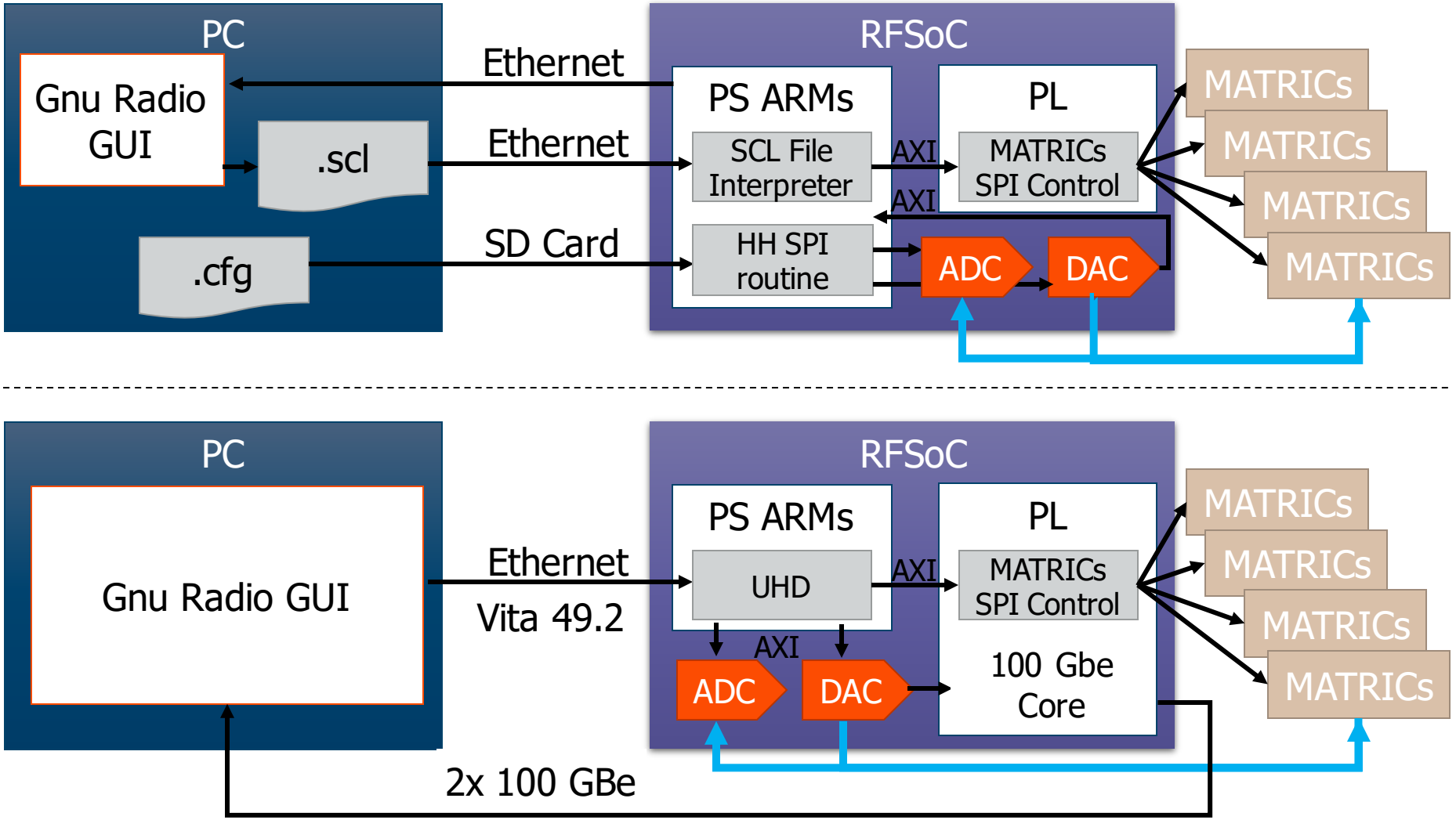


Alpha Hedgehog Module (RF Side)



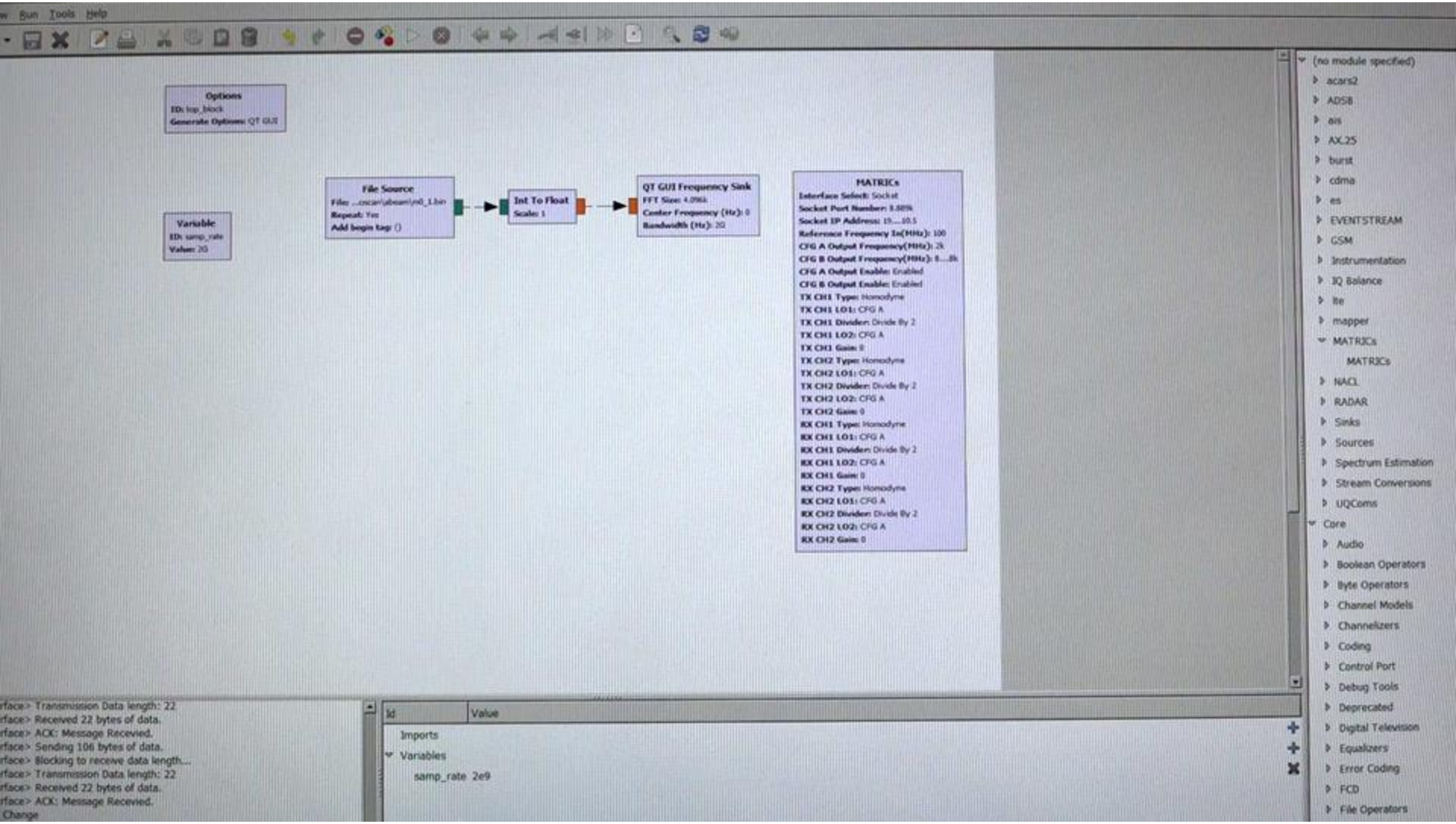


Programming on Hedgehog

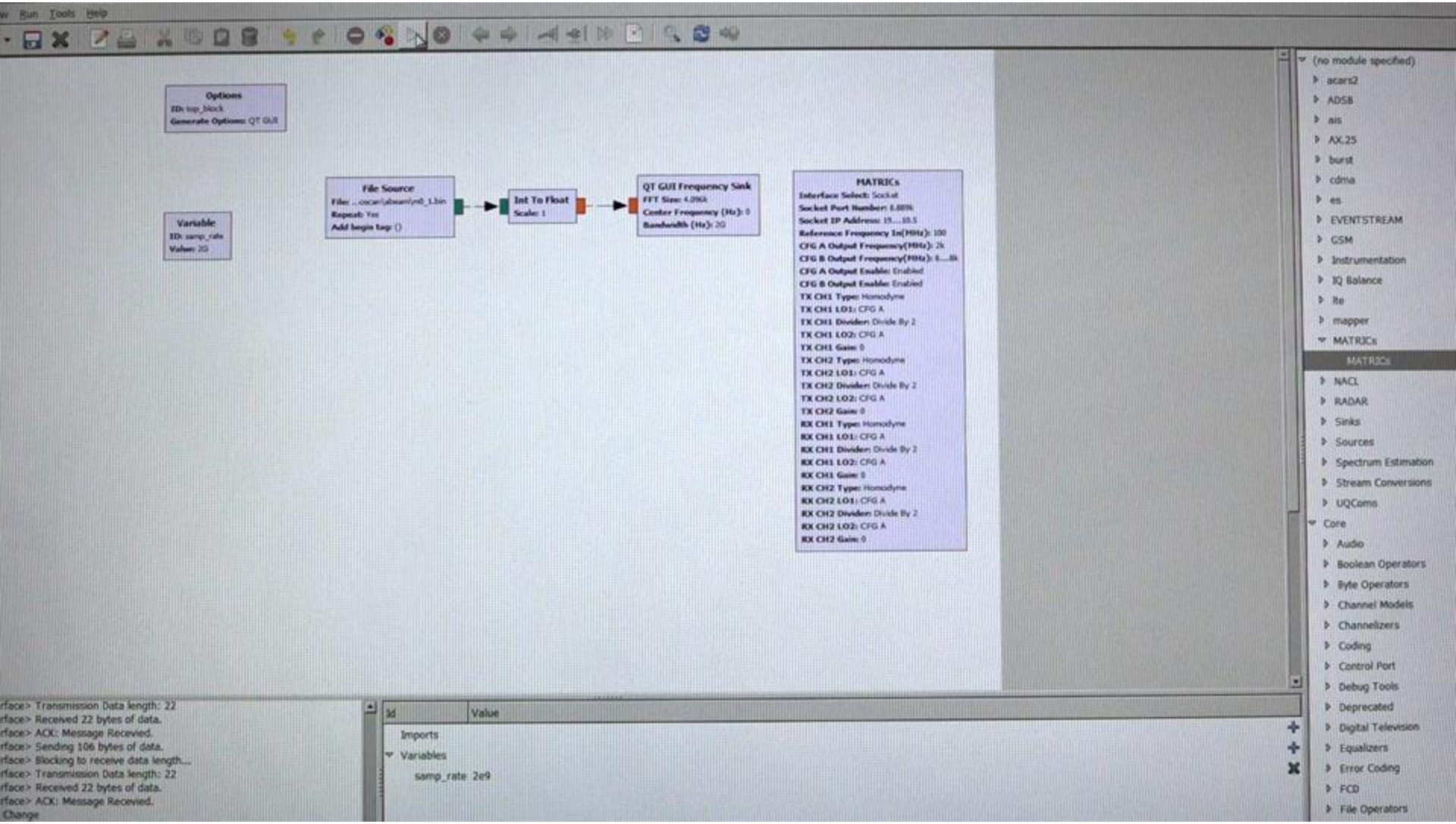


Demonstration Walkthrough

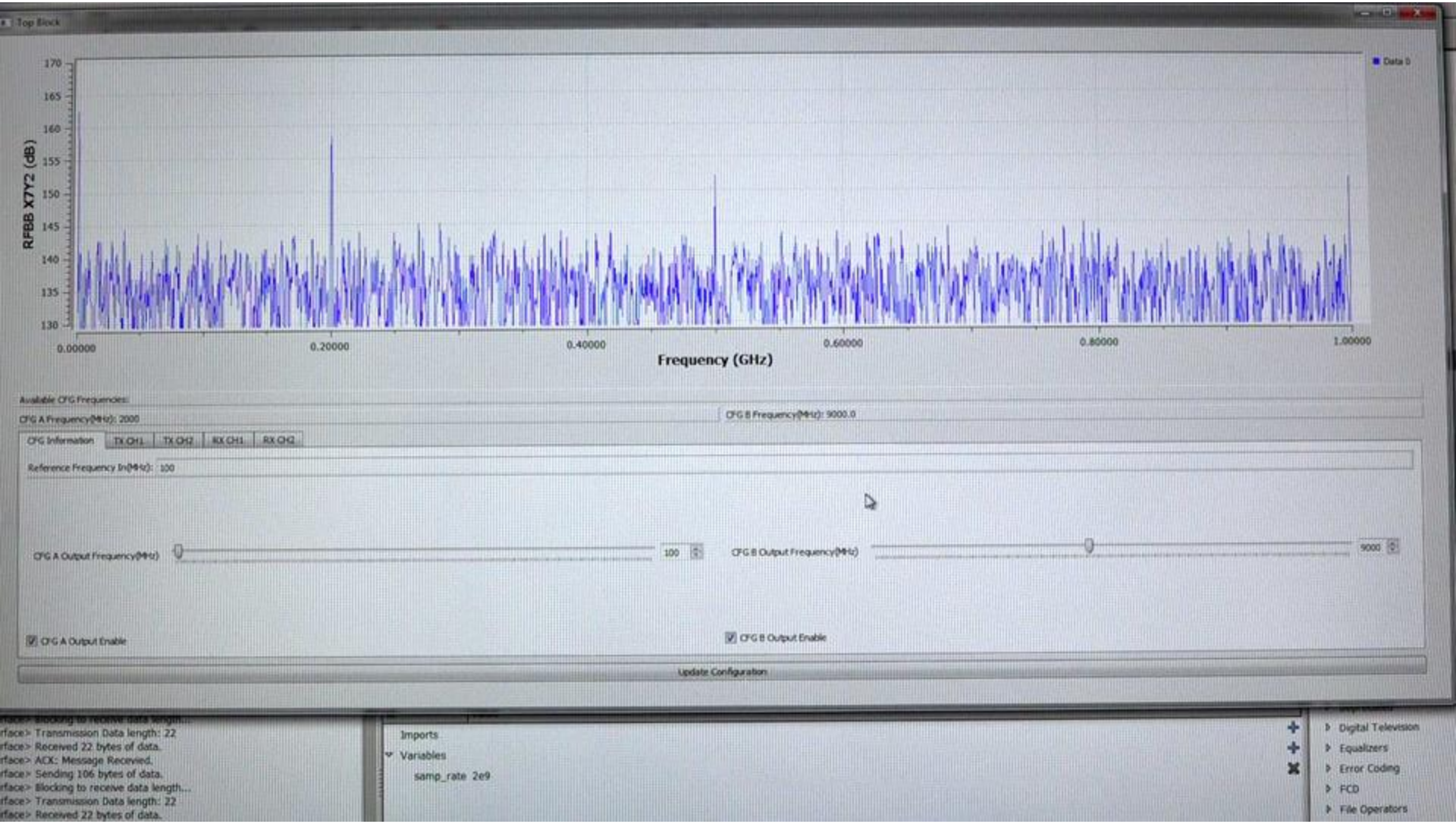
Demo Part 1



Demo Part 2



Demo Part 3



Acknowledgments

- Tom Rondeau, Janet Liu, David Kirkwood, and the rest of the government team under DARPA/MTO Hedgehog Program, Contract No. FA8650-17-C-7709

- Steve Hary & Brandon Mathieu, AFRL

- Mike Scott, Dave Howard, Ed Priesler, Jazz Semiconductor

- Manuel Uhm, Doug Johnson, Dan Baker NI/Ettus Research