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# Intro to SDR and Pluto


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WWW.ANALOG.COM/RADIOVERSE

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# Agenda

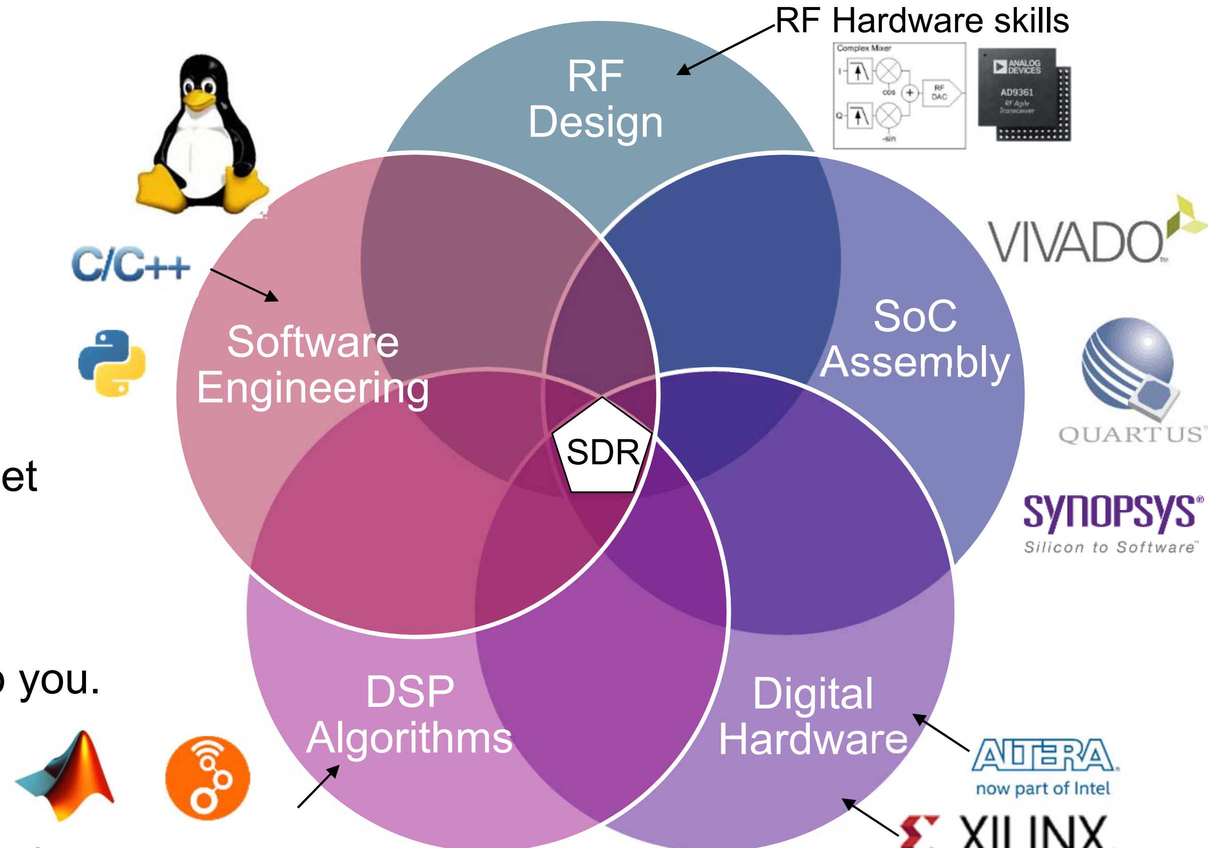
- Challenges in Getting Started with SDR
- Zero intermediate frequency (ZIF) radios vs. Super-Heterodyne radios
- Catalina (AD9361), Mykonos (AD9371), and Talise (ADRV9009) high-level overviews
- AD9361
- AD9371
- ADRV9009
- Getting Started with Pluto (aka AD936x)
  - Installing IIO Scope and Pluto Drivers
  - Lab Exercises
    - Lab 1: Transmit and Receive a Tone
    - Lab 2: Play Data and View Constellation
    - Lab 3: Receive and Re-Transmit an FM Radio Station

# Challenges in Getting Started with SDR

- Software Defined Radio requires:
  - Hardware Engineers
  - Software Engineers
  - Communications Engineers
  - HDL Engineers
  - Systems Engineers

- So with so much entailed, how can we get started with SDR?

- ADI Has Hardware **and** Software to help you.




Communications theory

$$s[2\ell N+n]=\frac{1}{2N}\sum_{k=0}^{2N-1}p_k[\ell]e^{j(2\pi nk/2N)},$$

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# Design Flow

**Research**
- Behavioral Simulation
- Streaming data to MATLAB and IIO-Scope

**Algorithm Development**
- MATLAB reference implementation
- Hardware streaming

**Design Elaboration**
- MATLAB
- Simulink modeling
- Hardware streaming
- Data type conversion

**Prototype**
- Deployment to development board
- Design optimization
- HDL Integration
- Driver Integration

**Production**
- Deployment to custom hardware
- Validation with complete hardware solution

PlutoSDR

RFSoM+FMC Carrier or Eval FMC + FPGA Carrier

PackRF or RFSoM + Custom Carrier

Custom

# ADI’s Hardware Prototyping Environment

### ADALM-PLUTO
- AD9363
- 1 x Rx, 1 x Tx
- *325 MHz – 3.8GHz*
- 200kHz – 20 MHz channel bandwidth

### AD-FMCOMMS2
### AD-FMCOMMS3
- AD9361
- 2 x Rx, 2 x Tx
- *tuning range*
  - *2.2 GHz – 2.6GHz*
  - *70 MHz – 6GHz*
- 200kHz - 56 MHz channel bandwidth

### AD-FMCOMMS4
- *AD9364*
- *1 x Rx, 1 x Tx*
- 70 MHz – 6GHz tuning range
- 200kHz - 56 MHz channel bandwidth
- Shipping Now

### ARRADIO
- AD9361
- HSMC, not FMC
- 2 x Rx, 2 x Tx
- *2.2 GHz – 2.6GHz tuning range*
- 200kHz - 56 MHz channel bandwidth
- Shipping Now!

### AD-FMCOMMS5
- *2 x AD9361*
- *4 x Rx, 4 x Tx*
- *Synchronized RF*
- 70 MHz – 6GHz tuning range
- 200kHz - 56 MHz channel bandwidth
- Shipping Now!

### ADRV9371-N/PCBZ
### ADRV9371-W/PCBZ
- *AD9371*
- *2 x Rx, 2 x Tx, 2 x Obs, 1x Sniffer*
- tuning range
  - *1.8GHz – 2.6GHz*
  - *300MHz – 6GHz*
- Tx synthesis bandwidth 250 MHz
- Rx BW: 8 MHz to 100 MHz

### ADRV9375-N/PCBZ
### ADRV9375-W/PCBZ
- *AD9375*
- *2 x Rx, 2 x Tx, 2 x Obs, 1x Sniffer*
- tuning range
  - 1.8GHz – 2.6GHz
  - 300MHz – 6GHz
- *DPD actuator and adaptation engine for PA linearization*

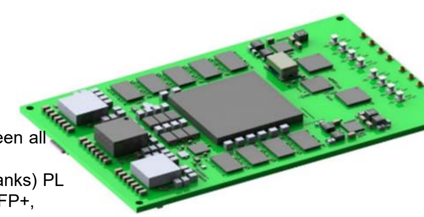
### ADRV9008-1W/PCBZ (Rx)
### ADRV9008-2W/PCBZ (Tx/Obs)
### ADRV9009-W/PCBZ (TDD)
- *ADRV9008-1, ADRV9008-2, ADRV9009*
- *2 x Rx, 2 x Tx, 2 x Obs, 1x Sniffer*
- 75MHz - 6GHz tuning range
- Tx synthesis bandwidth 450 MHz
- Rx BW to 200 MHz

### ADRV9364-Z7020
### ADRV9361-Z7035
- *AD9364 + Zynq 7020*
- *AD9361 + Zynq 7035*
- 70 MHz – 6GHz tuning range
- 200kHz - 56 MHz channel bandwidth
- 1GB DDR + 32MB FLASH
- Ethernet + USB Phy

### PACKRF
- *ADRV9361 reference design*
- Battery, PoE, Screen, Audio, GPS, IMU

### ADRV-DPD1
- *AD9375 + 250 mW PA*
- 2 Rx, 2 Rx
- LTE Band 7
  - 2500 to 2570 Uplink
  - 2620 to 2690 MHz Downlink
- 2 PAs, 2 LNAs, duplex filters

### ADRV9009-ZU11EG
- *2 x ADRV9009 + Zynq Ultrascale*
- 75MHz to 6GHz tuning range
- Rx BW 200MHz
- Tx synthesis bandwidth 450 MHz
- Integrated LO and Phase synch between all channels and Modules
- 4G x64 w/ECC PS; 4G (2Gb x32 x2Banks) PL
- USB3, USB2, PCIe 3.0 x8, QSFP+, SFP+, 1Gb Ethernet x2, and CPRI



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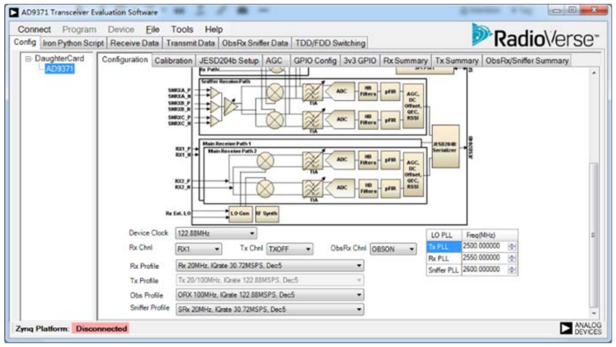
# ADI's Software Prototyping Environment: 4 Main Tools

- IIO Oscilloscope
  - Built on the IIO LIB Linux Drivers
  - Data Visualization Application
  - Graphical Configuration Application
- TES GUI
  - For the AD937x and ADRV9008/9 products
  - Evaluation and Python Scripting




- GNU Radio
  - Free Linux Based Graphical Communications Toolbox
  - Great intro to concepts and algorithm development
  - Pluto and AD936x products supported, not AD937x or ADRV9008/9
  - But for prototype and production, better to move to Matlab
- Matlab / Simulink
  - All ADI Transceivers Supported in Matlab
  - Evaluation → Verification → Detailed Design → Prototype
  - See Next Slide for Seminar Details

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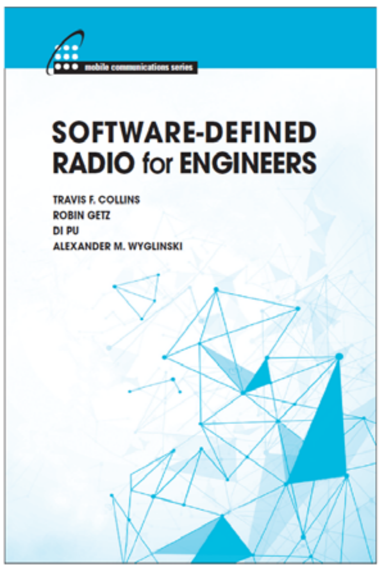
# Rapid Prototyping of RF Systems with Software Defined Radio

**THIS WORKSHOP IS COMING TO A CITY NEAR YOU SOON!**

Hard cover text




ADALM-PLUTO SDR


MATLAB Trial

| Time | Presenter | Topic |
|---|---|---|
| 8:00 – 8:30 | Richardson | • Check In / Coffee<br>• Pick up hardware and Textbook |
| 8:30 – 9:00 | Analog Devices<br>MathWorks | • Debug Software Installation Issues<br>• Check Connectivity to hardware |
| 9:00 – 9:10 | Richardson | Introductions |
| 9:10 – 9:45 | Analog Devices | • ADI Prototyping Ecosystem (RadioVerse)<br>• AD9361 (chip)<br>• Pluto SDR (system)<br>• Instructor lead demo of dump1090 |
| 9:45 – 10:00 | MathWorks | Model Based Design |
| 10:00 – 10:45 | Analog Devices | IIO infrastructure and Software Tools<br>• capture and control radio with IIO command line tools, and the IIO Oscilloscope<br>• Hands on labs (Coffee) |
| 10:45 – 11:15 | MathWorks | MATLAB and Simulink and system objects<br>• Hands on labs |
| 11:15 – 11:30 | Analog Devices | Data Flow and Transfers |
| 11:30 – 12:30 | Analog Devices | Basic communications theory<br>• Hands on labs |
| 12:00 – 12:30 | Lunch | • Hands on labs (Working lunch) |
| 12:30 – 12:45 | MathWorks | Advanced Workflows |
| 12:45 – 1:00 | Analog Devices | Moving to Custom Hardware |
| 1:00 – 3:00 | Analog Devices | Care and Feeding of your AD9361 / Pluto SDR<br>• Future Transceivers<br>• Hands on Lab (Coffee) |
| 3:00 – 4:00 | Richardson | Signal Chain<br>• LNA, PA, PLL, Filters, Up/Down converters & Power for RF Applications |
| 4:00 – 4:15 | All | Questions and Answers |

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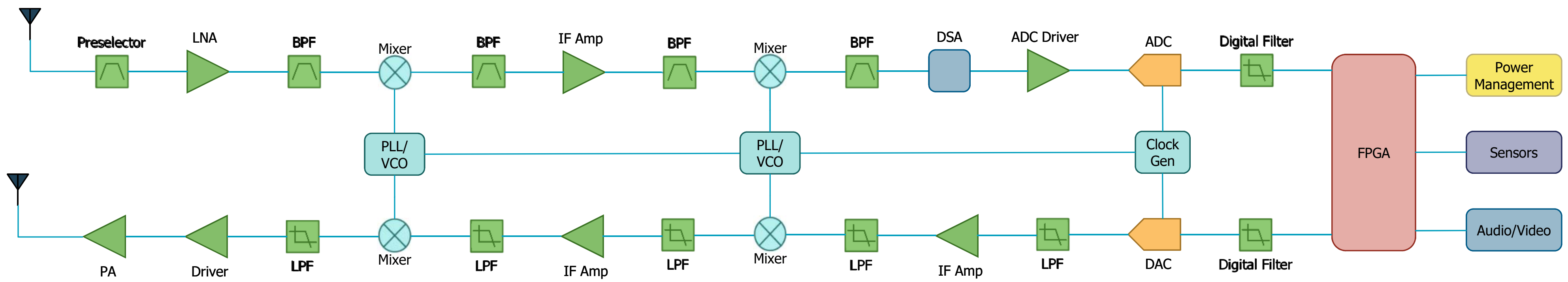
# ZIF Transceivers

COMPARISON TO SUPERHETERODYNE

# Super-Heterodyne Overview

- Introduced 100 years ago
  - Still dominates most designs, in radar and MILCOM/EW/SIGINT
  - Trusted technique, allows for incremental improvements across devices
- High performance at the sacrifice of large size and power
  - Filters, especially in the IF strips, drive this

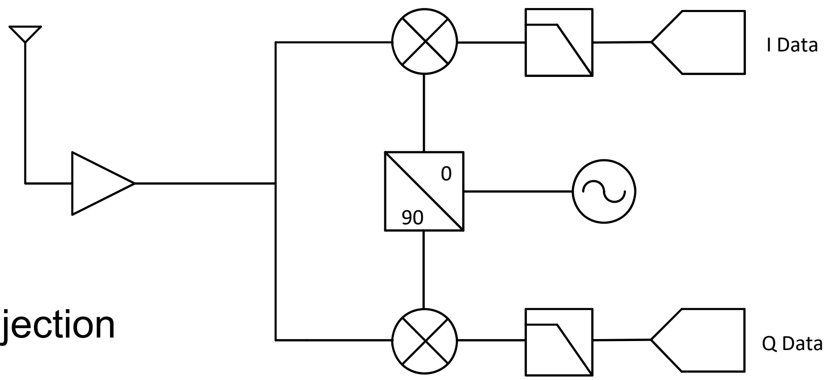


# Direct Conversion Overview

- Direct conversion attempts to simplify the super-heterodyne
- One mixing stage
  - LO = RF

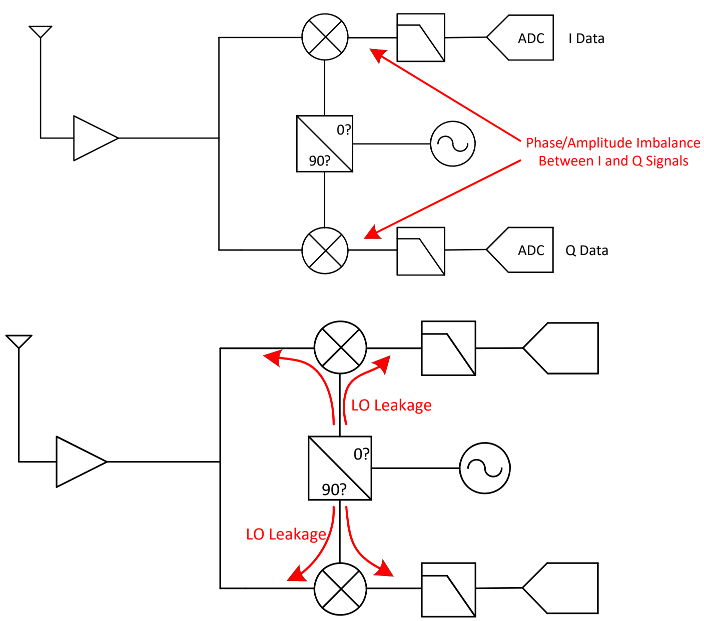
    → Rx goes directly to baseband

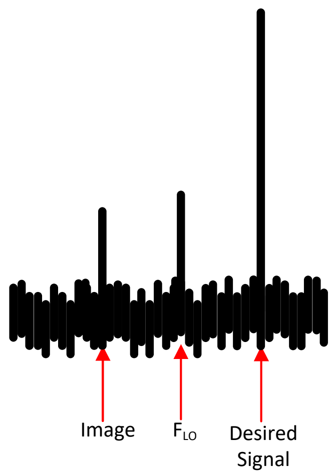
    → Tx goes directly to the desired RF frequency
- Removes filtering complexity in the design
  - Filtering takes place at baseband
  - But dependent on mixer performance for LO and image rejection
- Has numerous advantages over the superhet architecture
  - Filtering requirements less stringent
  - Significant reduction in power consumption
    - Resulting from reduced component count and reduced sample rate
  - Significant cost reduction
    - Resulting from reduced component count and filtering requirements



# ZIF Architecture Problems

- Disadvantages over Superhet architecture
  - Inherent performance issues
    - I/Q phase/amplitude imbalance degrades image rejection
    - Poor LO isolation passes LO to RF (LO Leakage) and baseband (DC Offset)
  - Performance depends heavily on calibrations



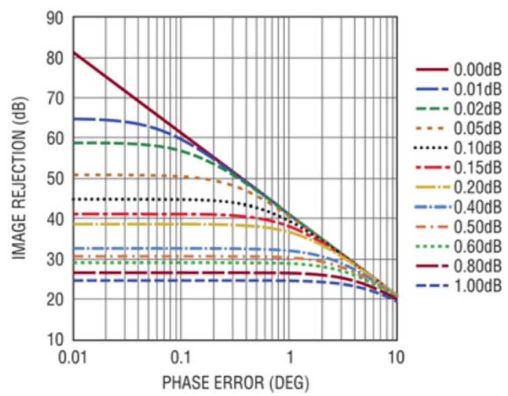




Figure C. Image Rejection vs Phase Error for Different I/Q Gain Mismatch

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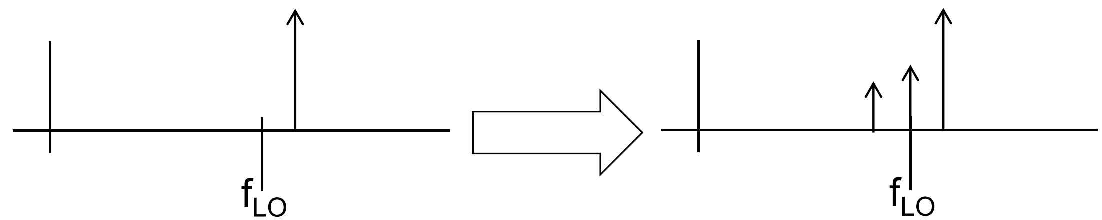
# Direct Conversion Challenges

- Real Scenario
  - I and Q data may be ideal, but…
    - 90 degree splitter is not perfectly accurate
    - Isolation between LO and RF is not infinite
    - DC bias in the two paths are not evenly matched




  - These imperfections create image products and DC/LO products (Rx/Tx)
- Discrete direct conversion struggles to correct these errors
  - Image and DC/LO levels often 30-40dBc from carrier
- One of the primary enablers of the ADI transceivers is the correction algorithms
  - AD9361 achieves ~50dB rejection
    - Good, but a real IF ADC with a digital DDC is significantly better
  - AD9371 achieves ~75dB rejection
    - Transceiver performance is becoming competitive with super-het/real IF, and offers significant integration and power benefits
  - ADRV9009 is ~90dB rejection

# Summary of ZIF Architecture Comparison To Superhet

| ZIF | | Superhet |
|---|---|---|
| Low | Component Count | High |
| Low | Power Consumption | High |
| Transitioning to Medium/High | Performance | Medium/High |
| Low | Cost | High |
| High (enables multi-function, common platform radio) | Market Potential | Stagnant |

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# Zero IF SDR Transceivers

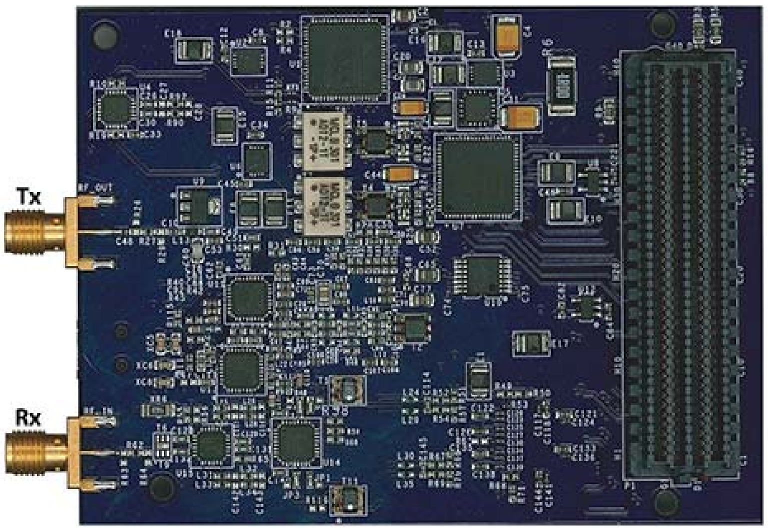
## Catalina (AD936x)

## Mykonos (AD9371)

## Talise (ADRV9008/9)

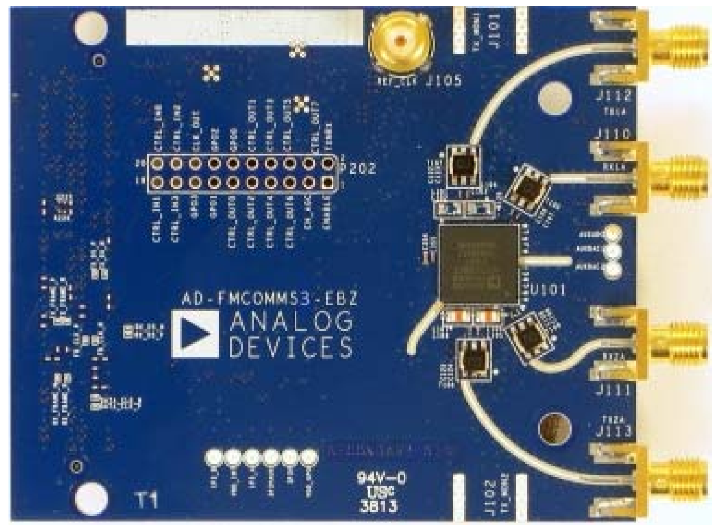
HIGH-LEVEL OVERVIEWS

# Size and Power of Two ZIF Solutions




## AD-FMCOMMS1

- Discrete ZIF, direct RF
- 1Rx, 1Tx
- 400 MHz – 4GHz tuning range
- 200+ MHz channel bandwidth
- Power, Clocks, ADC (AD9625), DAC (AD9162), PLL, DVGA
- Radio Power Consumption=4.5W




## AD-FMCOMMS3

- AD9361 Integrated
- 2 x Rx, 2 x Tx
- 70 MHz – 6GHz tuning range
- 200kHz - 56 MHz channel bandwidth
- Power, AD9361
- Radio Power Consumption=0.7W

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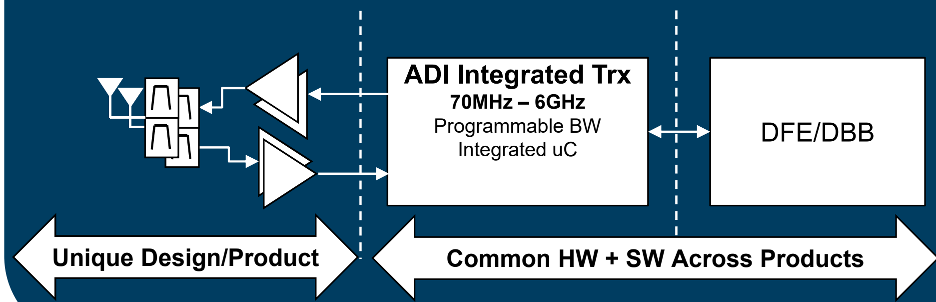
# Wideband RF Transceiver Benefits

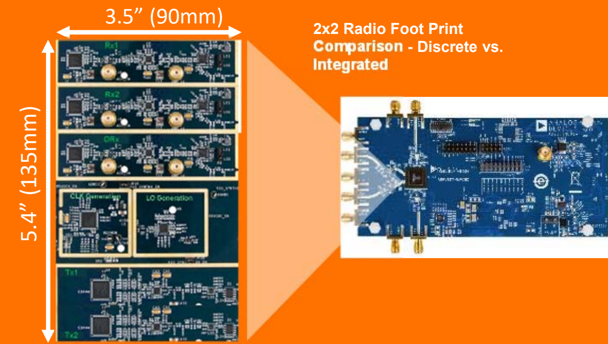
## Highly Reconfigurable

Enables reduced time to market through common HW & SW Small Signal Radio Platform




## Highest Level of Integration

Enables higher density radio architectures e.g. M-MIMO

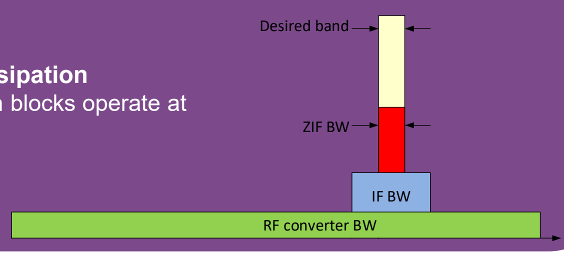



## Lowest Power Consumption

Reduce thermal density, enable lower SWAP radios

**Lowest possible power dissipation**

- Highest power consumption blocks operate at minimum bandwidth




## Lowest System Cost

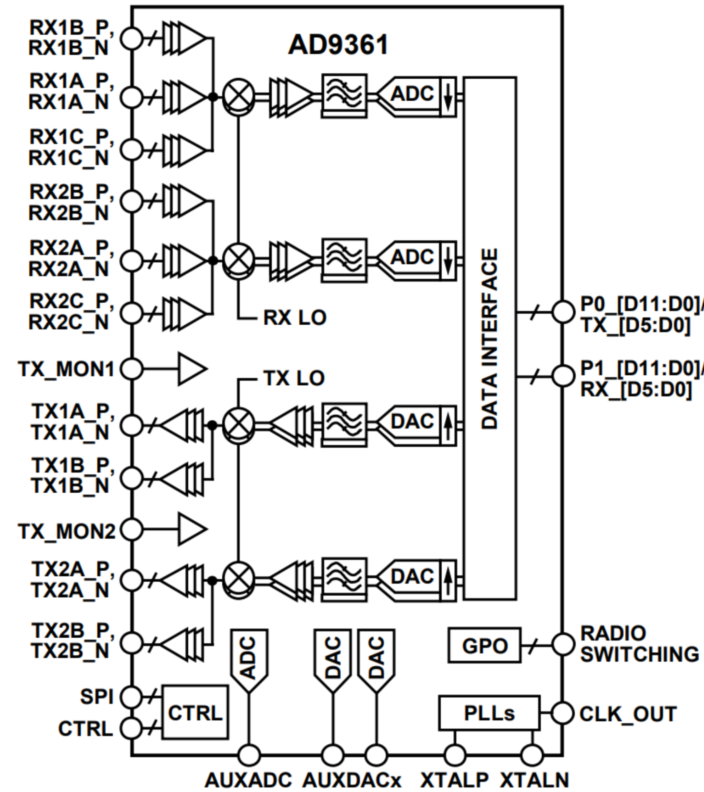
**Re-use of architecture used in handsets**

- Components such as IF filters are eliminated
- RF filters are simplified enabled by the elimination of out-of-band images or aliases

# AD9361: 2Rx/2Tx Integrated RF Transceiver (Catalina)

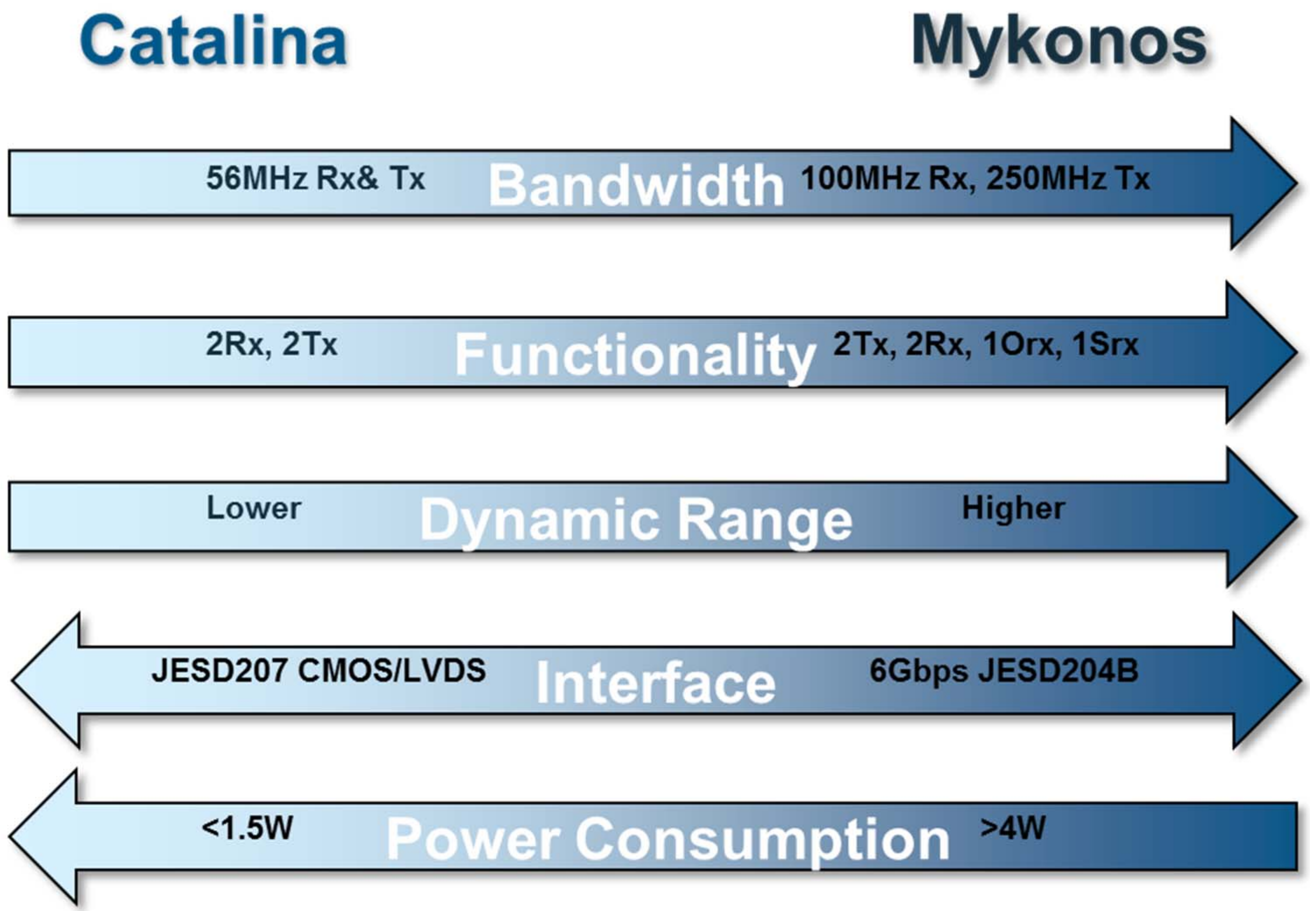
- ▶ 2Rx / 2Tx integrated RF transceiver
  - Tuning range: 70 MHz to 6GHz
  - Tunable channel BW:  200KHz to 56MHz
  - FDD/TDD operation


- ▶ Performance and power
  - Rx:  2.5dB NF
  - Tx: < -42dB Tx EVM
  - Tx Noise < -157dBm/Hz noise @ 70 MHz offset
  - Tx monitor: > 66dB dynamic range with 1dB accuracy
  - 12 bit ADCs/DACs
  - Phase noise: 0.25° @ 2.5 GHz
- ▶ Digital features
  - Rx:  DC offset correction, quadrature calibration, AGC, programmable FIR filters
  - Tx: quadrature calibration, programmable FIR filters
- ▶ Typical power: 800-1100 mW
  - 2Rx & 2Tx, 20 MHz BW, 0 dBm Tx power




| Temp | Package |
|---|---|
| -40°C – +85°C | 144- CSP_BGA (10x10mm) Pb-Free |

# AD9361 (Catalina) vs AD9371 (Mykonos)

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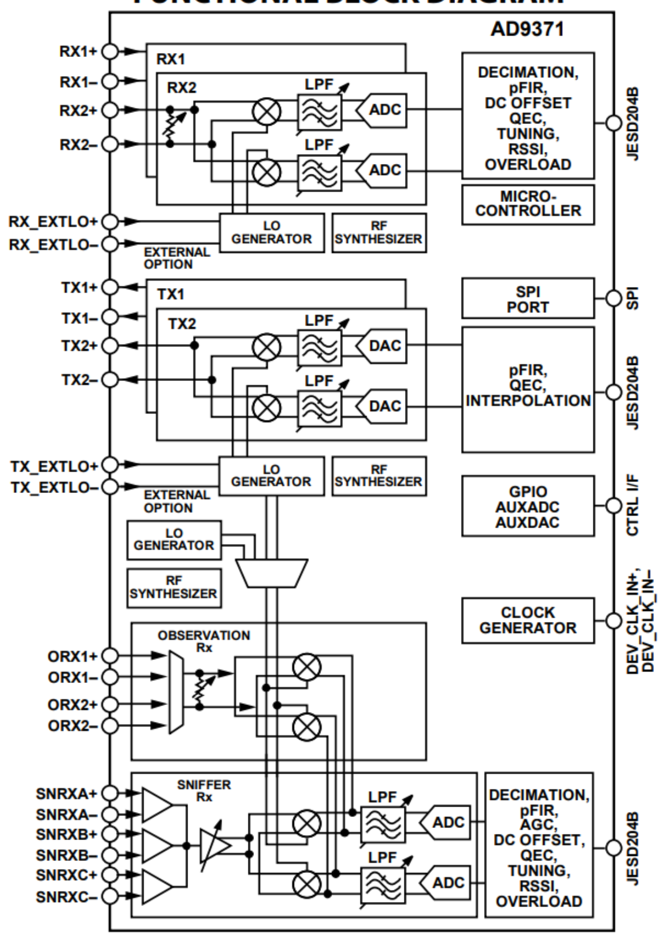
# AD9371 Integrated, Dual RF Transceiver With Observation Path (Mykonos)

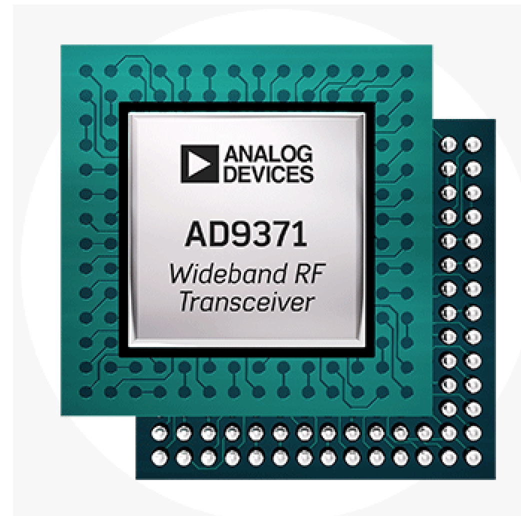
- Integrated dual-traffic Rx and Tx
  - Tuning range: 300MHz < Fc < 6GHz
  - FDD/TDD operation
- Receiver
  - Max Rx BW = 100MHz
  - NF: 12dB
  - $IIP_3$: 22dBm
  - $IIP_2$: 65dBm
  - Gain range/step (dB): 30/0.5
- Transmitter
  - Max Tx BW = 250MHz
  - -64dB ACLR (4 UMTS Carriers)
  - OIP3: 27dBm (5dB atten)
  - Gain range/step (dB): 42/0.05
- Integrated observation and sniffer Rx
  - Max ORx BW = 250MHz
    - 2 inputs
  - Max SRx BW = 20MHz
    - Contains LNA
    - Dedicated LO
    - 3 inputs
- Total power (@ max bandwidth)
  - 2x Rx = 2.7W
  - 2x Tx = 3.7W
  - 2x Rx, 2x Tx, ORx = 4.86W
- Digital features
  - Tx/Rx QEC, DC offset, LO leakage
  - 6GSPS JESD204-B interface

FUNCTIONAL BLOCK DIAGRAM




**Package**

196- CSP_BGA
(12x12mm) Pb-Free

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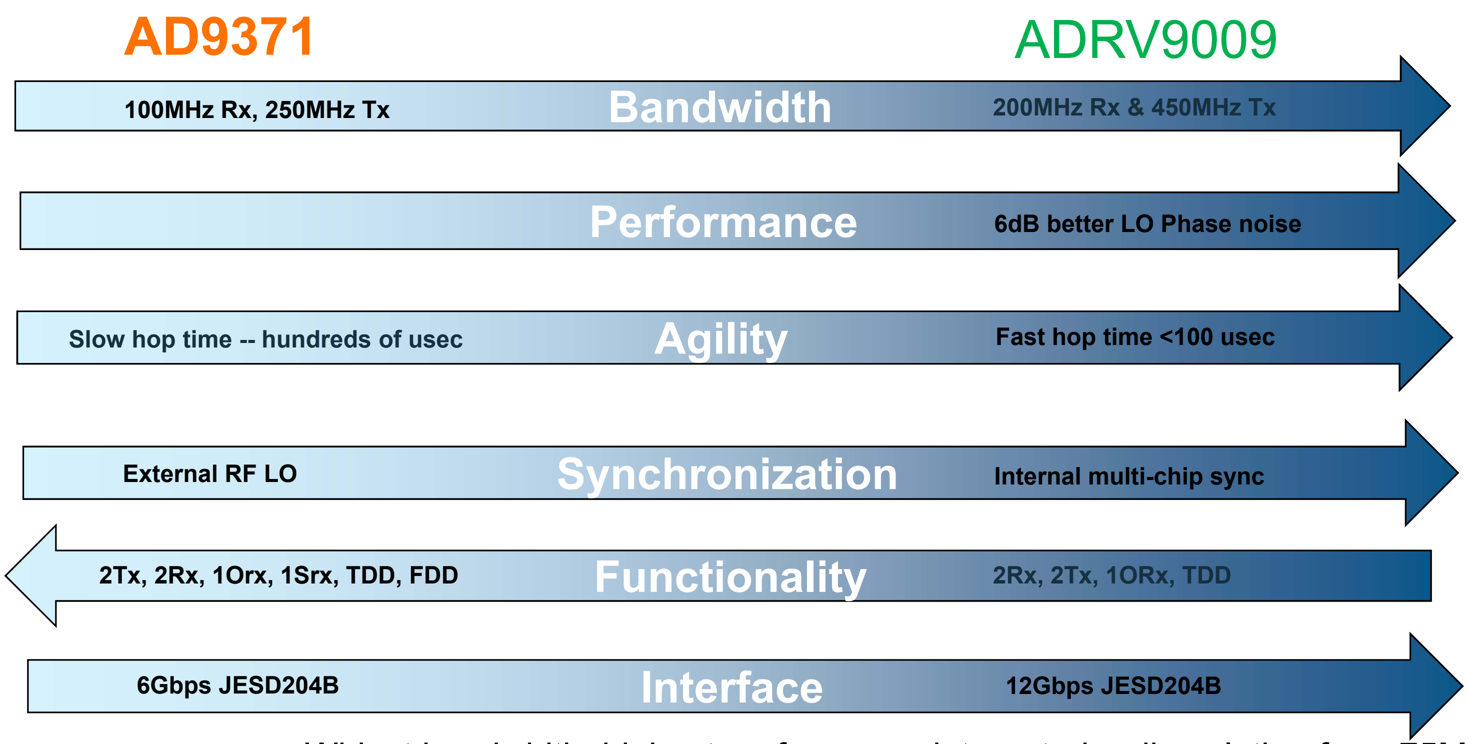
# AD9371 vs ADRV9009

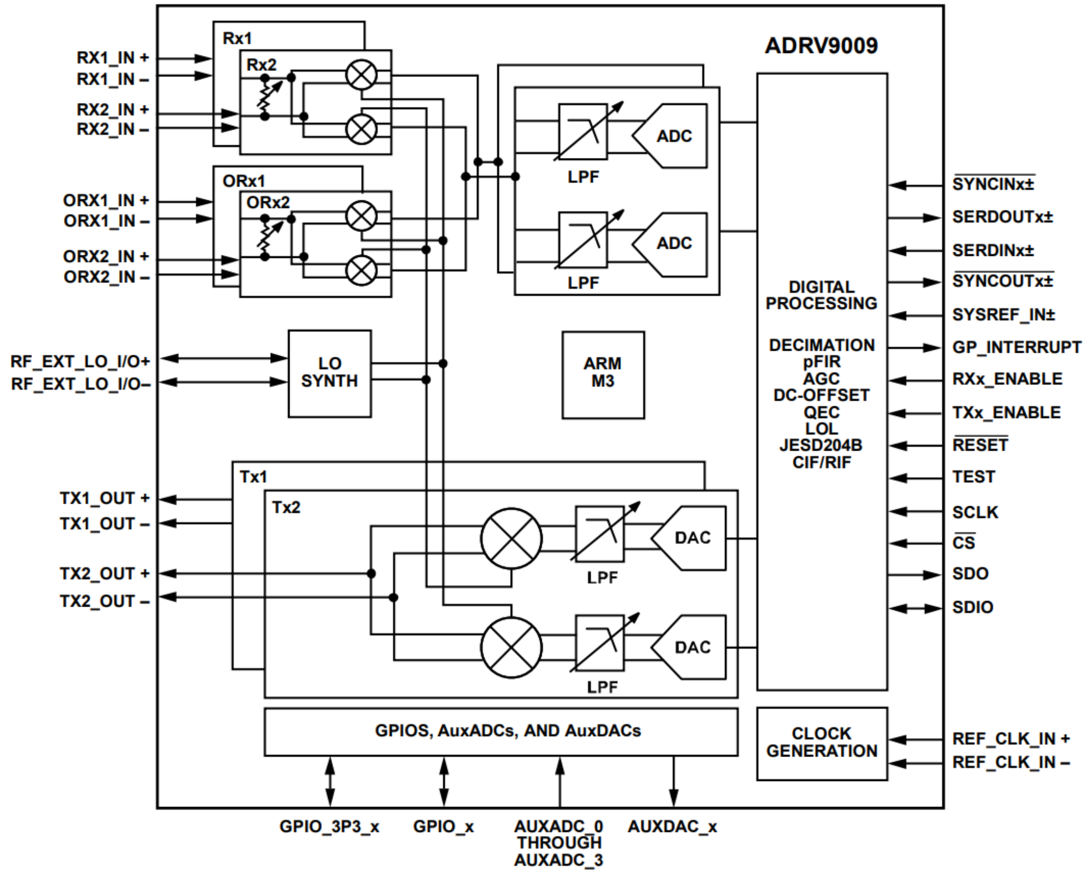



- Widest bandwidth, highest performance integrated radio solution from 75MHz to 6GHz
- Common platform design for 2G/3G/4G/5G base stations
- Supports multi-chip LO phase synchronization
- Enhanced frequency agility with fast frequency hopping and precalibration profiles

# ADRV9009 Functionality & Block Diagram

- **TDD operation**
- **Bandwidth:** 200 MHz receiver, 450 MHz transmitter and observation receiver
- **Integration:** dual transmitters, dual receivers and observation receivers with shared input
- **Tuning Range**: 75MHz to 6GHz
- **Interface:** 12 Gbps JESD204B
- **Power Consumption:** 4.6W*
- **Multi-chip LO phase synchronization**
- **Package:** 12x12 BGA

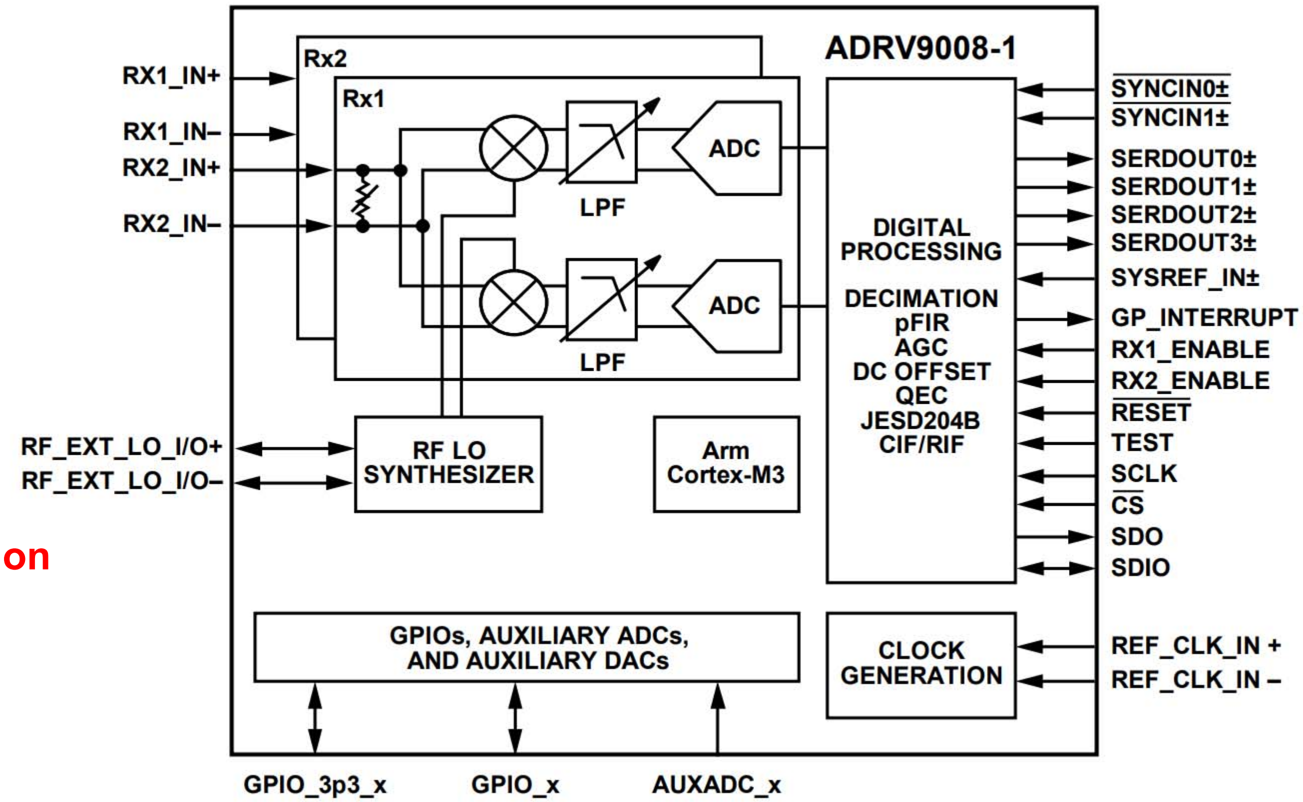
*For 50% Rx/Tx Duty Cycle, Orx on, 200MHz/450MHz BW, 0dB attenuation



# ADRV9008-1 Functionality & Block Diagram

- **FDD Rx operation**
- **Bandwidth:** 200 MHz receiver
- **Integration:** dual receivers
- **Tuning Range**: 75MHz to 6GHz
- **Interface:** 12 Gbps JESD204B
- **Power Consumption:** 2.48W*
- **Multi-chip LO phase synchronization**
- **Package:** 12x12 BGA
- Pin compatible with ADRV9009

*For 2Rx, 200MHz BW







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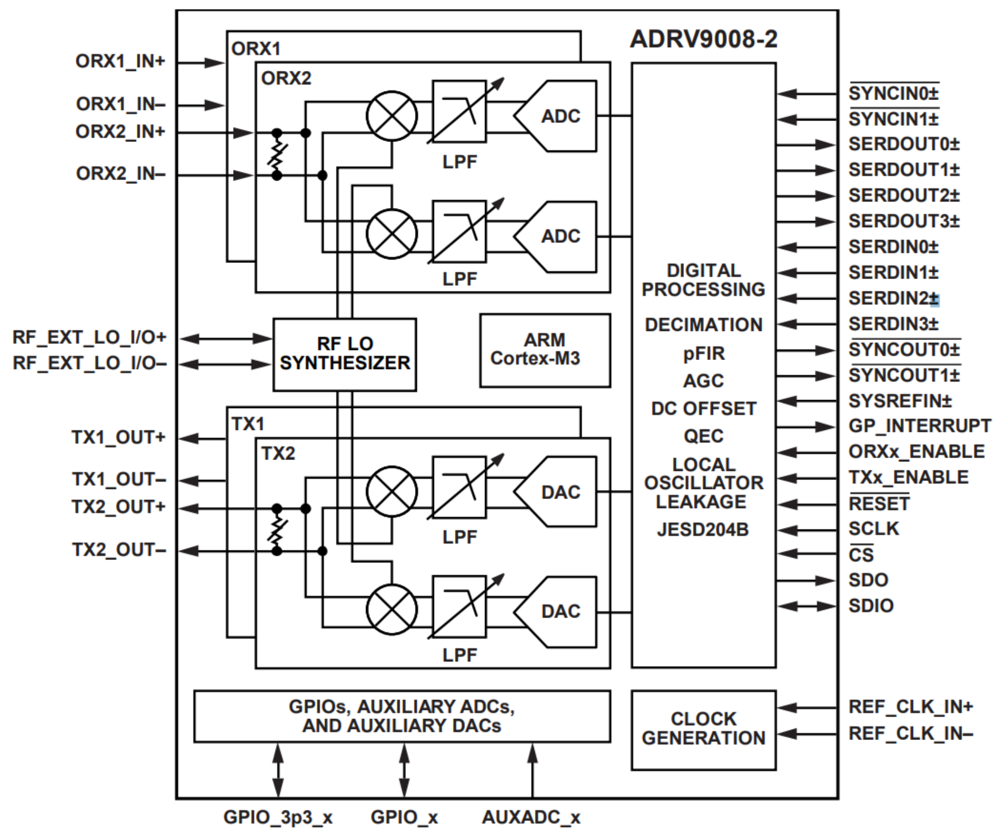
# ADRV9008-2 Functionality & Block Diagram

- **FDD Tx/Orx operation**
- **Bandwidth:** 450 MHz transmitter and observation receiver
- **Integration:** dual transmitters, observation receiver with dual inputs
- **Tuning Range**: 75MHz to 6GHz
- **Interface:** 12 Gbps JESD204B
- **Power Consumption:** 4.34W Tx, 1.25W Orx *
- **Multi-chip LO phase synchronization**
- **Package:** 12x12 BGA
- Pin compatible with ADRV9009




*For 450MHz BW, 0dB attenuation

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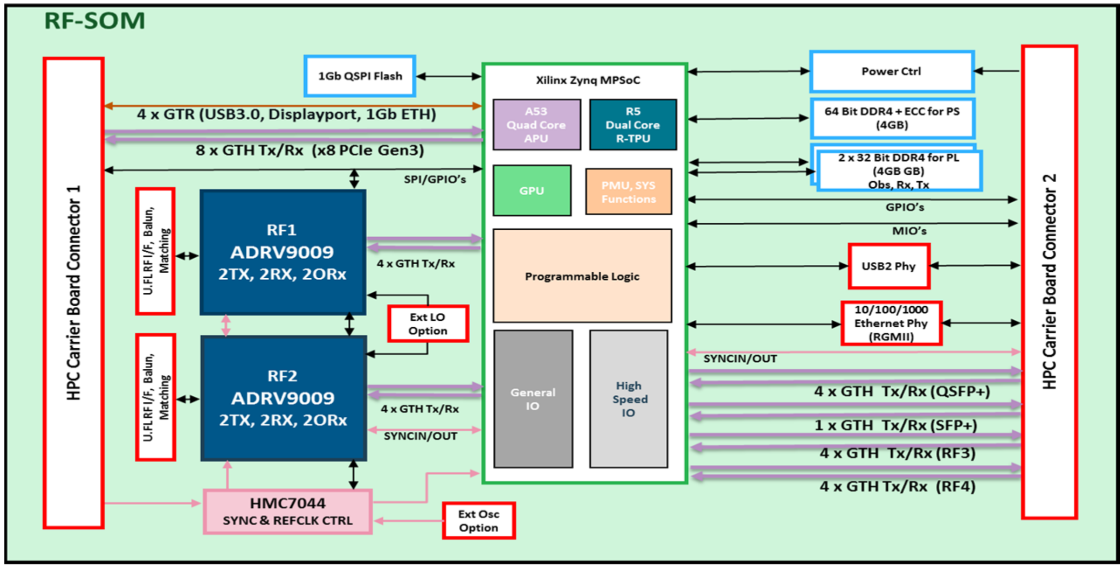
# Introduce ADRV9009 System-on-Module (RF-SOM)

- Supports up to 4x ADRV9009 that can be synced in Freq & Phase
- Scalable with multiple RF-SOM's synced together
- I/O connector: USB 3.0, 10Gb Ethernet, PCIe x8
- 96mm x 160mm
- Comes with open source code support package hosted on GitHub
- Qualified 'production ready' module to speed up prototyping and integration into final production.
- Allows customers to focus on their own areas of differentiation
- Broad range of applications in cellular infrastructure, radar, portable defence and instrumentation

**Engineering Sample Available in 2018Q4**







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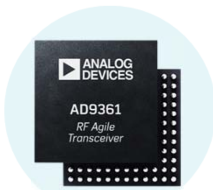
# Wideband RF Transceiver Portfolio Released on RadioVerse™




| Part # | Applications | Bandwidth | Functionality | RF Tuning Range | Rx Image Rejection* | Rx NF/IIP3** | Tx OIP3* | EVM | Package Size | Data Interface | Price |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **AD9361** | 3G/4G Picocell, SDR, Pt-Pt, Satcom, IoT Aggregator | 56 MHz | 2 Rx, 2 Tx | 70 MHz to 6 GHz | 50B | 3dB/-14dBm | +19dBm | -40 dB | 10 mm × 10 mm | CMOS/LVDS | $175 |
| **AD9364** | 3G/4G Picocell, SDR | 56 MHz | 1 Rx, 1 Tx | 70 MHz to 6 GHz | 50dB | 3dB/-14dBm | +19dBm | -40 dB | 10 mm × 10 mm | CMOS/LVDS | $130 |
| **AD9363** | 3G/4G Femtocell, UAV, Wireless Surveillance | 20 MHz | 2 Rx, 2 Tx | 325 MHz to 3.8 GHz | 50dB | 3dB/-14dBm | +19dBm | -34 dB | 10 mm × 10 mm | CMOS/LVDS | $80 |
| **AD9371** | 3G/4G Macro BTS, Massive MIMO, SDR | 100MHz Rx, 250MHz Tx | 2Tx, 2Rx Orx & SnRx | 300 MHz to 6GHz | 75dB | 1.6dB/+2dBm | +27dBm | -40 dB | 12 mm × 12 mm | 6GHz JESD204B | $245 |
| **AD9375** | 3G/4G Small Cell, 3G/4G Massive MIMO | 100MHz Rx, 250MHz Tx | 2Tx, 2Rx Orx & SnRx | 300 MHz to 6GHz | 75dB | 1.6dB/+2dBm | +27dBm | -40 dB | 12 mm × 12 mm | 6GHz JESD204B | $325 |
| **ADRV9009** | 3G/4G/5G TDD macro cell, Massive MIMO, Phased array radar | 200MHz Rx, 450MHz Tx | 2Tx, 2Rx Orx | 75 MHz to 6GHz | 75dB | 1.6dB/+2dBm | +27dBm | -43 dB | 12 mm × 12 mm | 12GHz JESD204B | $319 |

* typical performance @ 2.6GHz
** AD9371 cascaded analysis with external LNA NF = 1.1dB, Gain = 19.5dB, IIP3 = 33dB (HMC8175A broadband LNA). Typical Performance @ 2.6GHz
** AD9361 assumes internal LNA, typical performance @ 2.6GHz



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# Intro to ADALM-Pluto

LEARN SDR CONCEPTS AND TOOLS WITH PLUTO!

# Agenda for Pluto Labs using IIO Scope

- Pluto Introduction
- Pluto Installation
  - Update Drivers (if necessary)
  - IIO Oscilloscope
  - Verify Installation
- Pluto Lab 1:  Transmit and Receive a Tone
- Pluto Lab 2:  Play Data and View Constellation
- Pluto Lab 3:  Receive and Transmit FM Radio
- Pluto Lab 4:  Transmit FM Radio between Two Plutos





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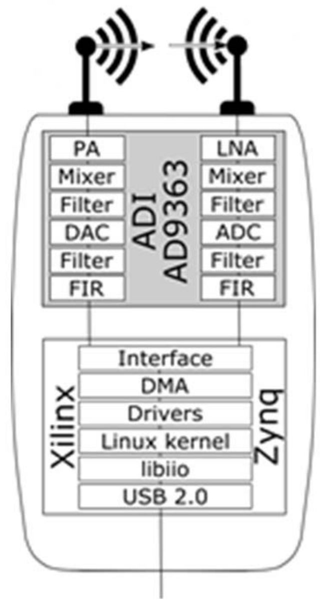
# Pluto is a Great Way to Get Started with Software Defined Radio!

- Pluto is a great way to get started with ADI's software defined radio products.
  - Pluto is a full AD9363 Transceiver with Xilinx Zync 7010 FPGA
  - The AD936x eval software and Design tools  work with Pluto
  - Pluto is a low cost ($150) solution to eval and learn the tools, vs. the full FPGA development boards ($4k)
- www.analog.com/adalm-pluto
- Use with:
  - ADI's IIO-Scope (same program that AD936x eval boards us
  - GNURadio, SDRangel, Matlab, etc.
- Free companion textbook here:
  - https://www.analog.com/sdrforengineers
  - Online lectures here:
    - https://www.youtube.com/playlist?list=PLBfTSoOqoRnOTBTLahXBlxaDUNWdZ3FdS









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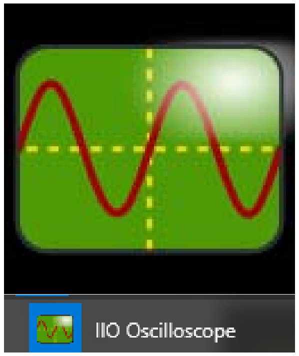
# Install Drivers and IIO Scope

- Download the USB drivers here:
  - https://github.com/analogdevicesinc/plutosdr-m2k-drivers-win/releases/download/v0.7/PlutoSDR-M2k-USB-Drivers.exe
- Download the LIBIIO drivers here:
  - https://github.com/analogdevicesinc/libiio
- Download IIO-Oscilloscope here:
  - https://wiki.analog.com/resources/tools-software/linux-software/iio_oscilloscope




- More info on Pluto here:
  - https://wiki.analog.com/university/tools/pluto/users

# Now Check Your Installation

- Plug Pluto into USB:
  - You should see the blue “Ready” LED is on, and the blue “LED1” is blinking
  - Only one USB cable is required.  Plug this into the middle port with the USB symbol.
    - The other USB port, with the power plug icon, is for power only.  So if you wanted to run an automated script on Pluto, with no computer connected, then you could power Pluto from this port.  But that’s a topic for another day….
- Then verify that the LIB IIO drivers have bene installed
  - Open the command prompt
  - Type “iio_info –s”
  - You should see something like this:

Command Prompt

```
Microsoft Windows [Version 10.0.14393]
(c) 2016 Microsoft Corporation. All rights reserved.

C:\Users\jkraft>iio_info -s
Library version: 0.15 (git tag: 6ecff5d)
Compiled with backends: xml ip usb serial
Available contexts:
        0: 0456:b673 (Analog Devices Inc. PlutoSDR (ADALM-PLUTO)),
 serial=104473222a8700101f0019003eadd5a19d [usb:1.6.5]

C:\Users\jkraft>
```

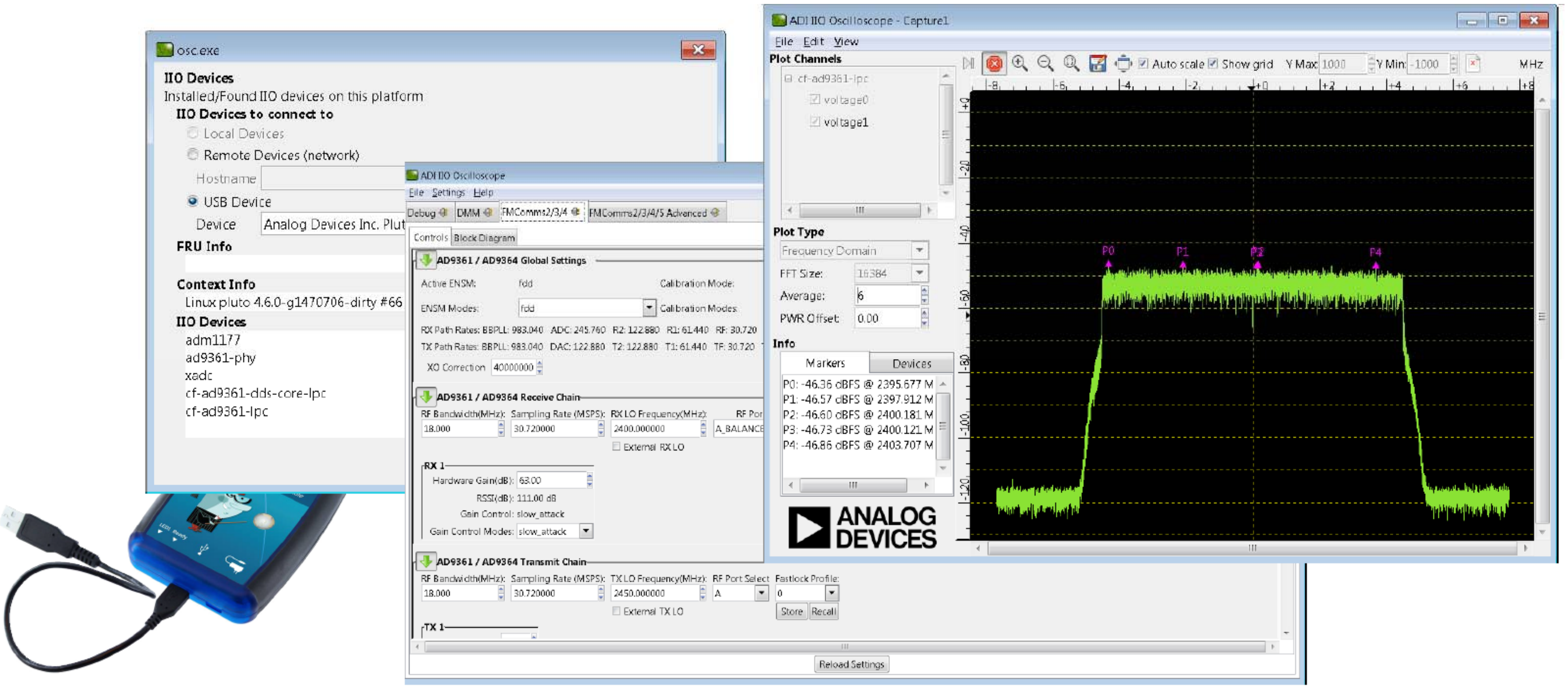
- Library version refers to the IIO scope driver library.  If you don’t see it, then you didn’t install IIO Scope drivers properly
- The serial number and USB information (i.e. 1.6.5) will be unique to your Pluto and computer.  But if you see it, then it means that your computer can see the Pluto device on USB

# Update Pluto (if necessary)

- Update Pluto Firmware here:
  - https://wiki.analog.com/university/tools/pluto/users/firmware
  - If you received your Pluto from Jon Kraft, FAE, then this has already been done for you!

- Widen the RF interface of Pluto to 70M to 6 GHz, and BW to 56MHz. Go to “Updating to the AD9364” on this page:
  - https://wiki.analog.com/university/tools/pluto/users/customizing
  - If you received your Pluto from Jon Kraft, FAE, then this has already been done for you!

# Plug in Pluto and Launch IIO Scope:





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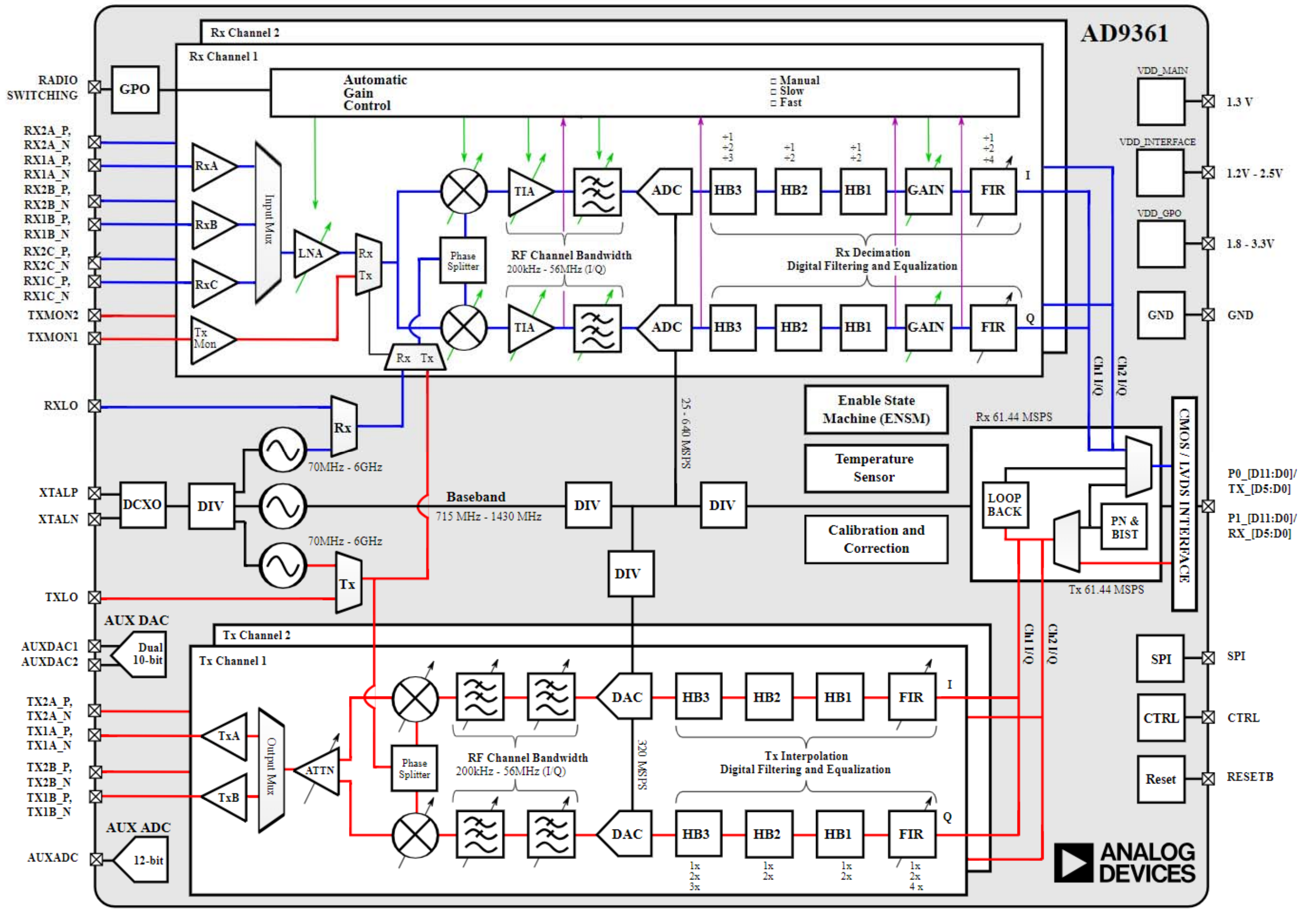
# Some Background Info Before We Start Our Labs

# Warning About Transmitting!

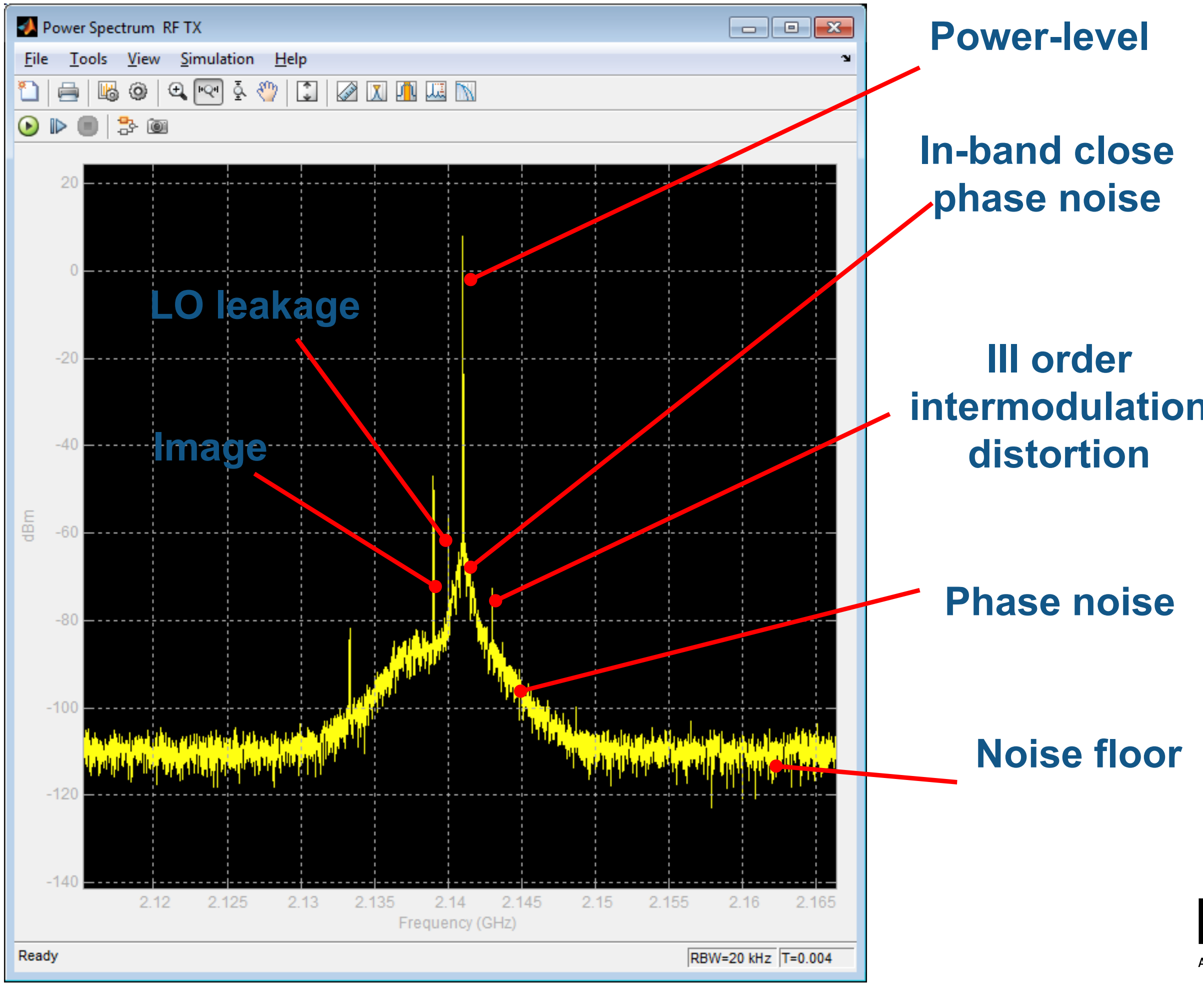

- Transmit only when and where you are legally allowed to!
- This is your responsibility to know.
- There are many emergency radio bands
  - https://en.wikipedia.org/wiki/International_distress_frequency
  - Note the civilian aircraft emergency band at 121.5 MHz.  Stay far away from this!!!!
- DO NOT transmit ANYTHING on any of these bands
  - Either intentionally or unintentionally (via harmonics)
  - These bands are always being watched and authorities will triangulate your “distress” call!
- Use the ISM bands!
  - 864 to 870 MHz, 2.4 to 2.5 GHz, and 5.725 to 5.875 GHz.
- So be careful about your settings!
  - Use Pluto’s programmable bandwidth filter to filter your transmissions to the MINIMUM bandwidth
  - Transmit at the MINIMUM power level (put your Tx antenna close to your Rx antenna)
  - Choose your LO frequency so that you are away from these bands.

- I am not a lawyer!  Nor am I offering legal advice!  Learn what is permitted in your country!
  - Here’s the FCC (USA) guidance for low power transmission in the FM Bands:
    - https://www.fcc.gov/media/radio/low-power-radio-general-information

# Details of the AD936x (Refer back to this slide during the labs)

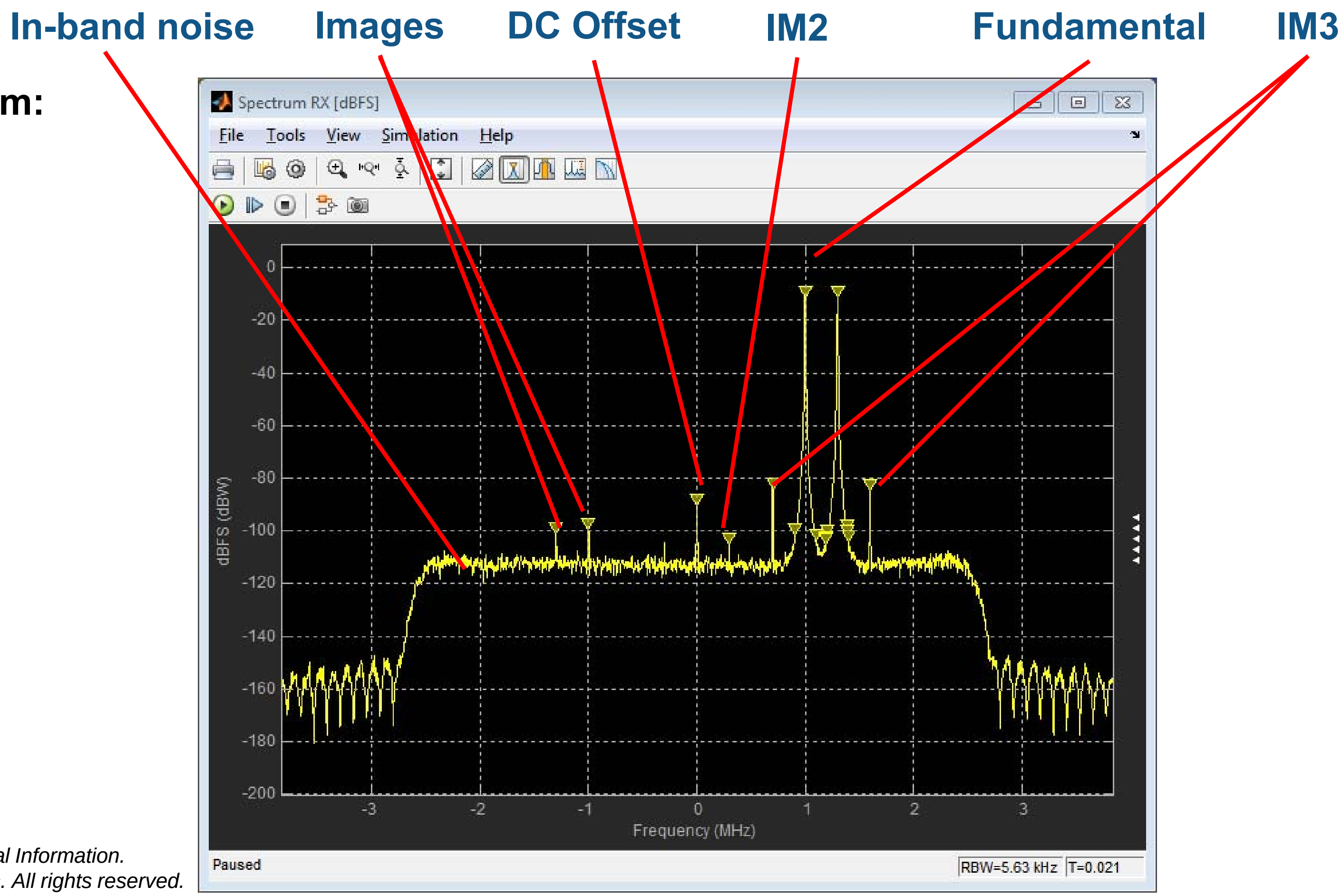


# Typical TX Spectrum for a Direct Conversion Receiver



# Typical RX Spectrum for a Direct Conversion Receiver

**Typical RX Spectrum:**







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# Pluto Lab 1:  Transmit and Receive a Tone

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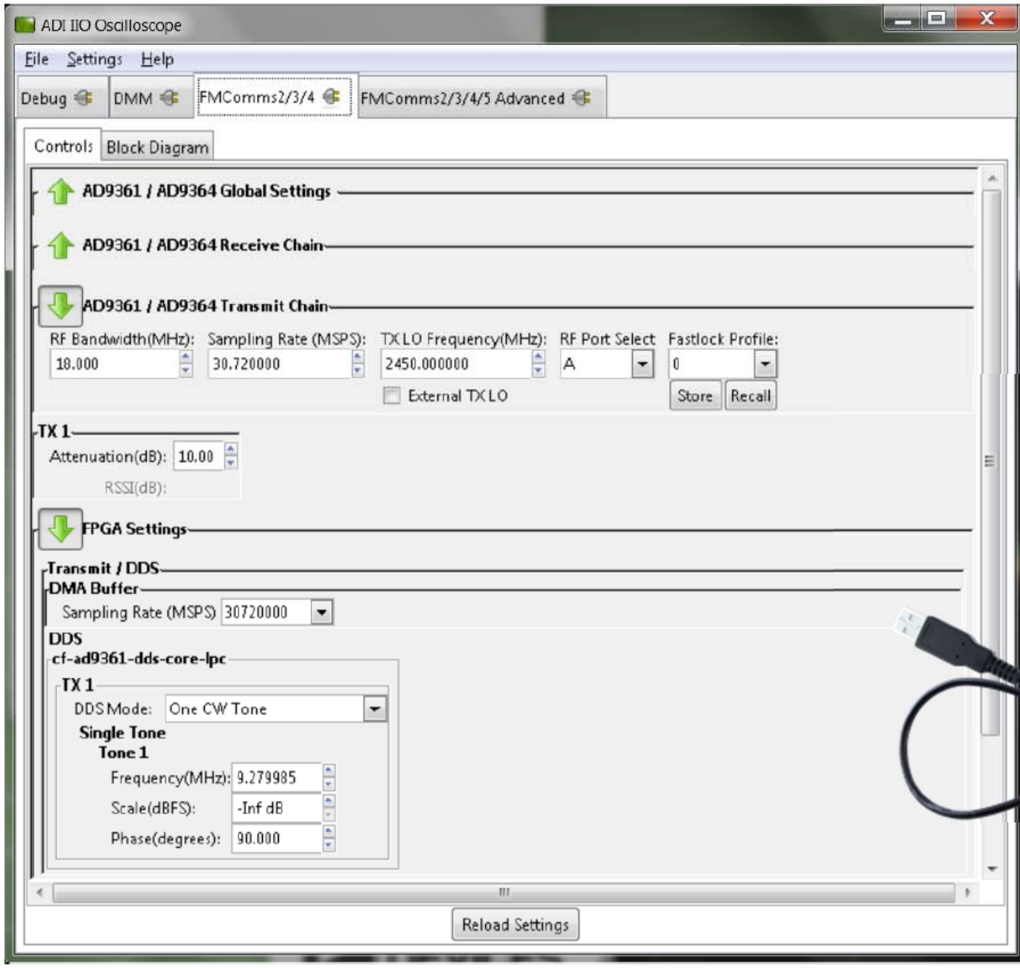
# Pluto Lab 1: Transmit and Receive a Tone

Controlling the output. From this window, you can examine and change the the RF bandwidth, the DAC sample rate, the Tx LO Frequency, and the signals that are being sent from the FPGA to the AD9363 inside the ADALM-PLUTO SDR.

For now, set things to a single tone at -3dB scale, at 30.72 MSPS, with a 18 MHz bandwidth, at a TX LO of 2450 MHz.





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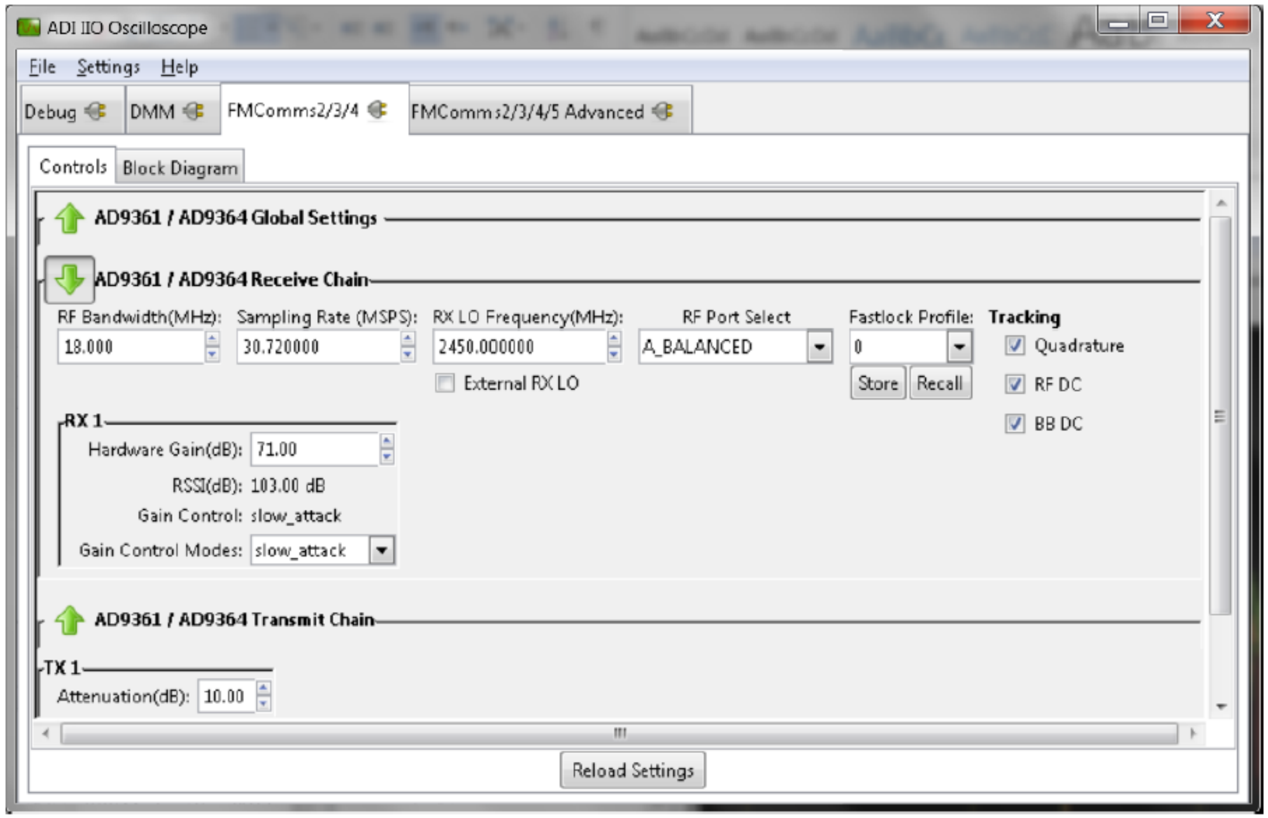
# Pluto Lab 1: Transmit and Receive a Tone

Set the Rx RF BW, Sampling Rate, RX LO, and AGC mode as shown.

Create a plot and explore things in the various domains: time, frequency and constellation

Observe the effect of FFT size and Average
- Average=0 is max hold
- Average=128 is min hold

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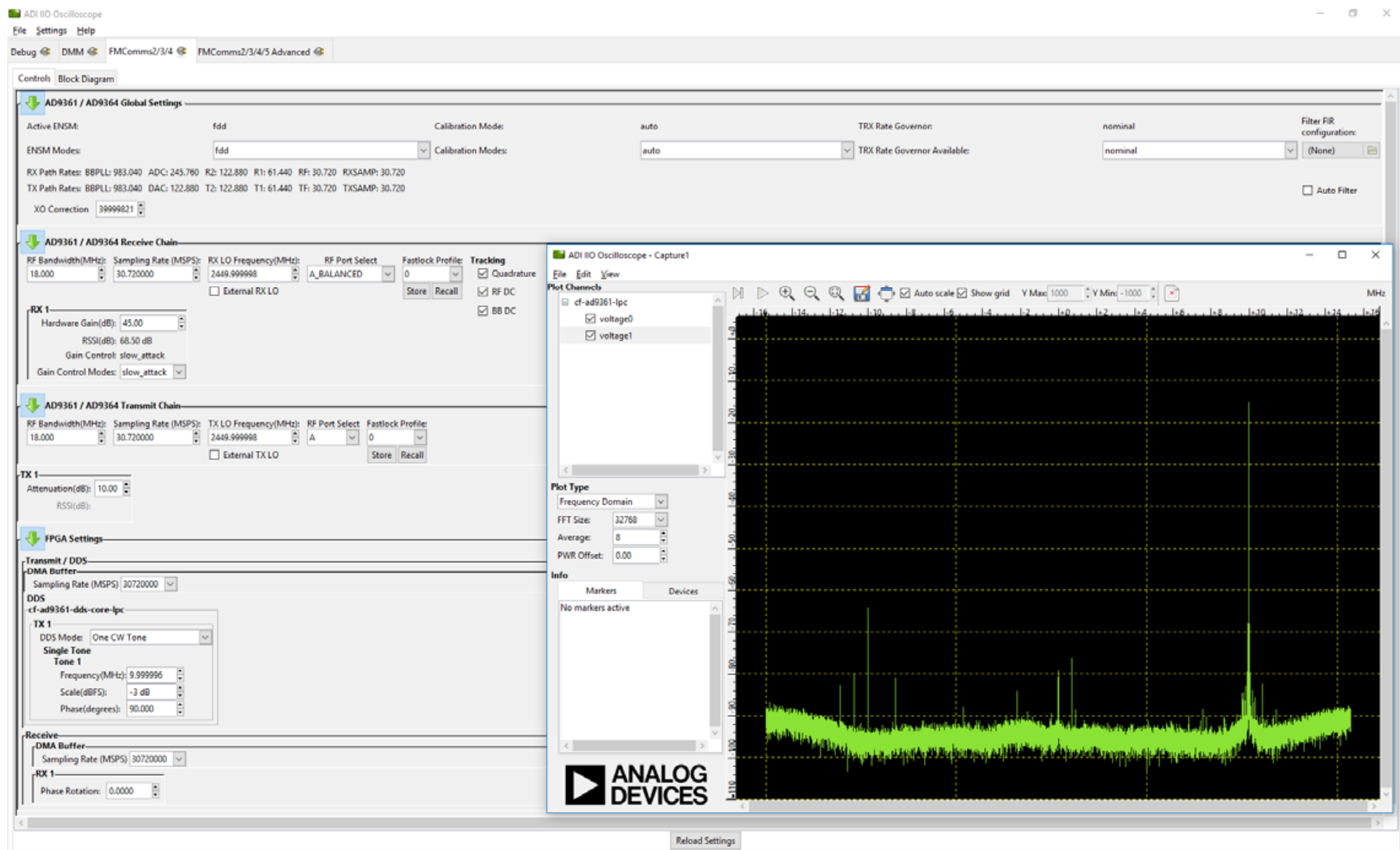
# Pluto Lab 1:  Transmit and Receive a Tone

Right click on the plot and select “Image Markers” or “Single Tone Markers”

Try unchecking some of the Tracking Calibrations

Try creating two tones
 3 MHz, 5 MHz,
-10dB per tone

Try changing TX1 attenuation from 10 dB to 20 or 30dB.
 - What happens to the spurs?
 - What happens to Hardware Gain?

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# Pluto Lab 2:  Play Data and View Constellation

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# Pluto Lab 2:  Play Data and View Constellation in IIO-SCOPE

Play back a file:
- Set DDS mode to “DAC Buffer Output”
- Select file (i.e. QPSKwithFILT_30.72M.txt)

Use the included 2.4 GHz antennas

Look at the Constellation
- Try using points, instead of lines
- Increase # of points to 8192 or 16384

Why are things rotated?

Apply a phase rotation to RX1

Then try it with the SMA cable connected to Rx and Tx




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# Pluto Lab 2:  Play Data and View Constellation in IIO-SCOPE

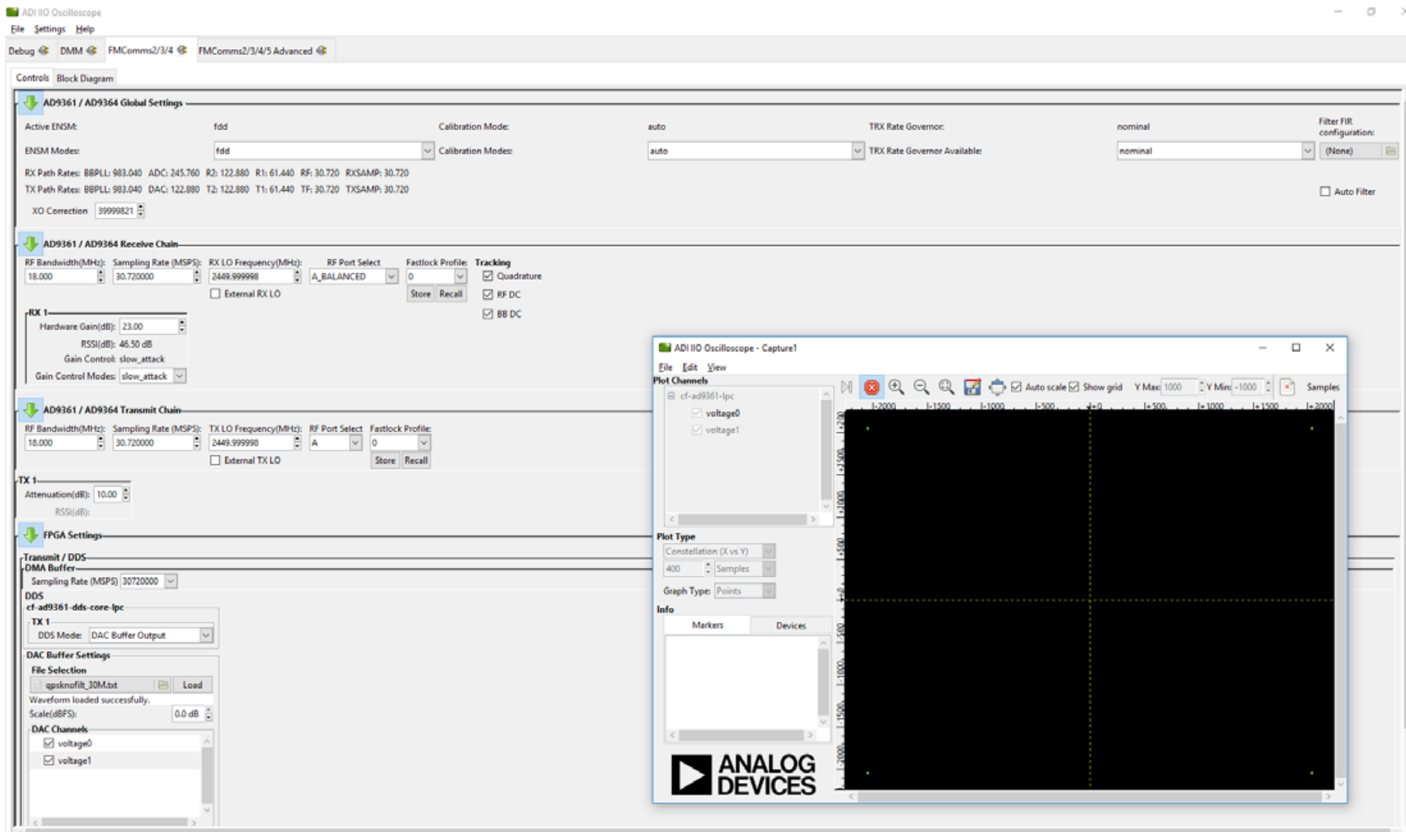
Load file:
QPSKwithFILT_30.72M.txt

Go to FMComms Advanced Tab

Under Loopback, select Digital TX->Digital RX

- Going into digital loopback let's you look at the file.
- Everything that is sent is looped back to the receive side

Look at the constellation now. You may need to add lines to see the points.

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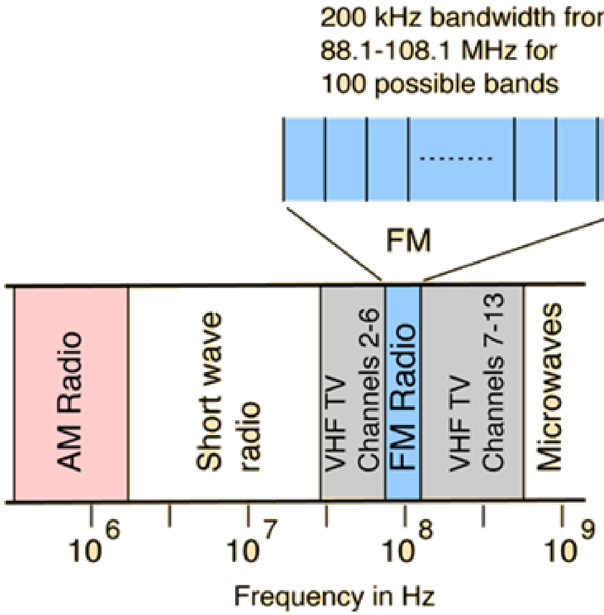
# Pluto Lab 3: Receive and Re-Transmit an FM Radio Station

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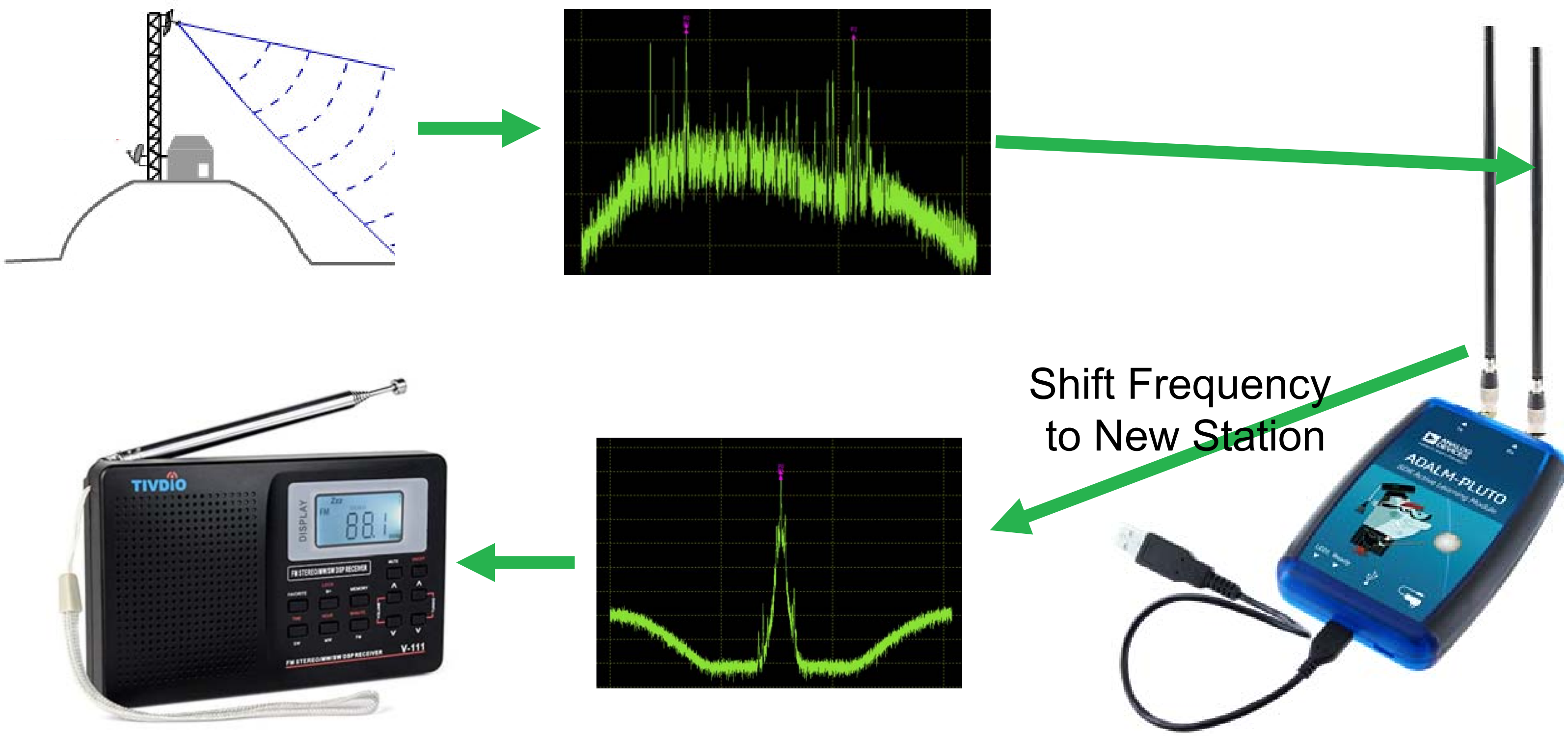
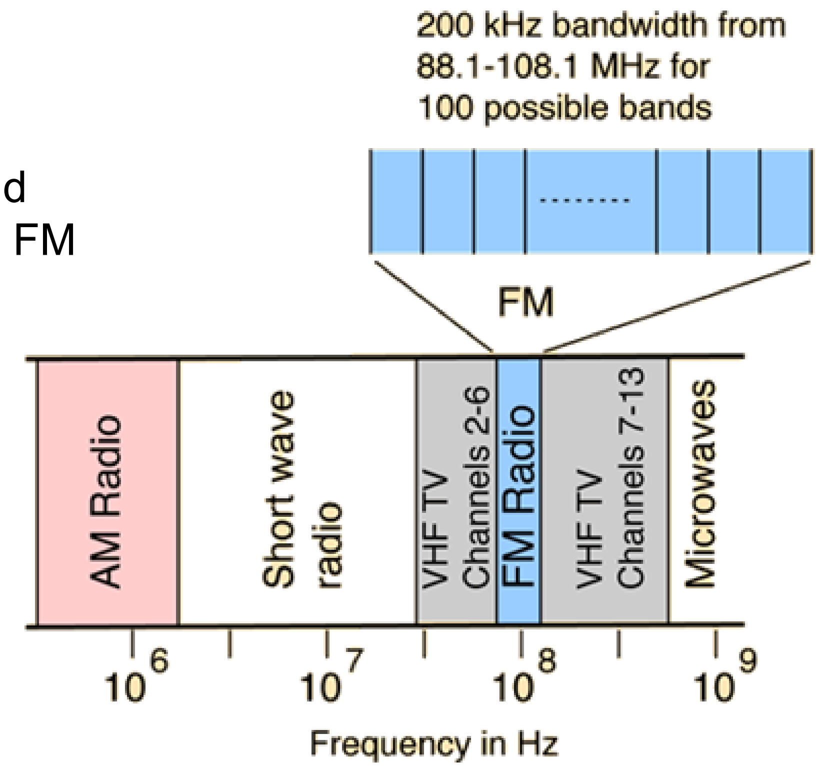
# Pluto Lab 3:  Rx and Tx FM Radio

- We’ll use Pluto to Receive, shift the carrier frequency, and then retransmit FM Radio station



# Pluto Lab 3: Rx and Tx FM Radio

- FM Radio is 87.9MHz to 107.9MHz (centered at 97.9 MHz)
- Each station is spaced 200kHz apart.
- The included Pluto antennas are GREAT at 2.4 GHz and EXTREMELY bad at 100MHz. You'll need to buy some FM Antennas.
- You'll want an FM Radio for parts of this lab.

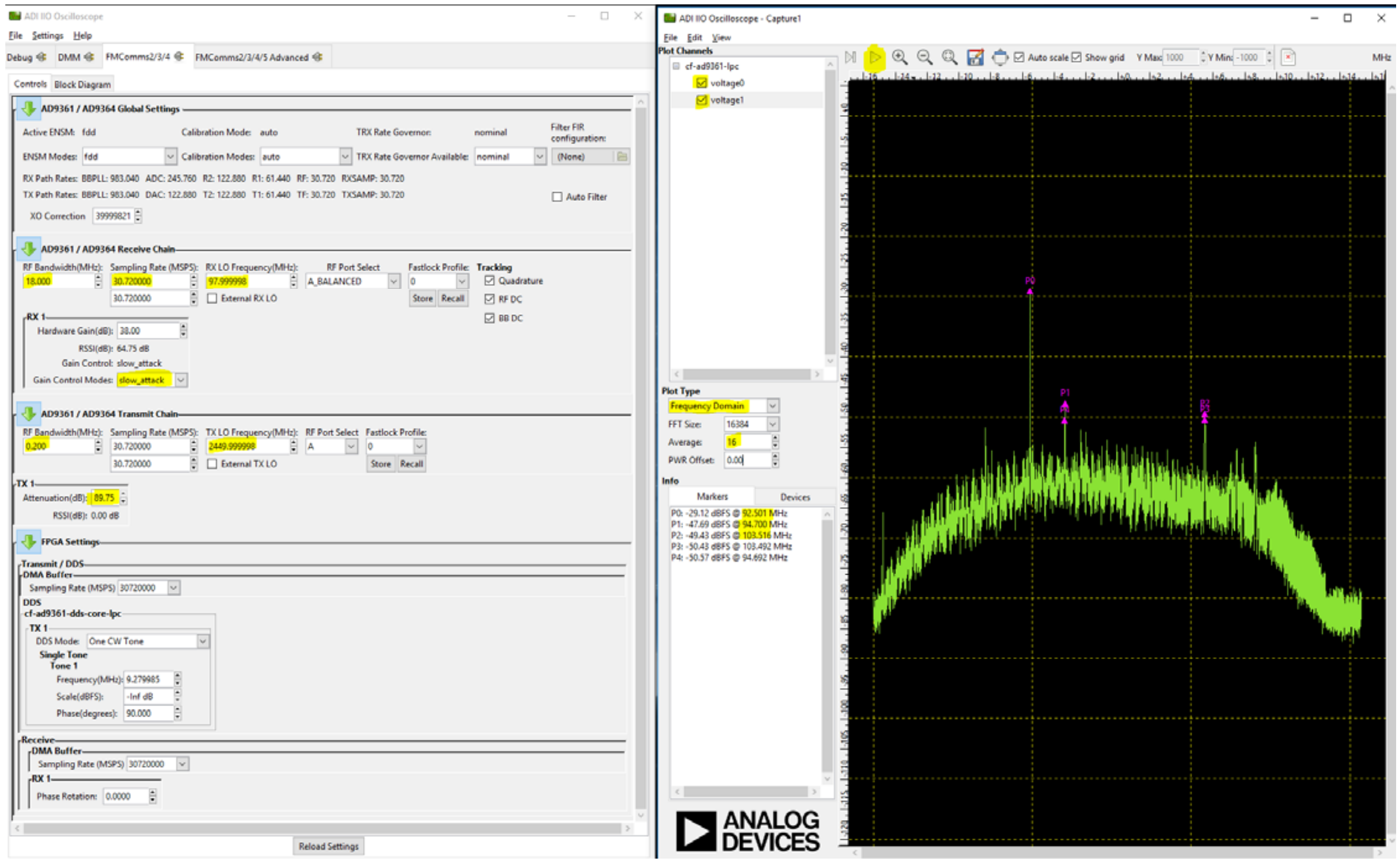



# Pluto Lab 3:  Rx and Tx FM Radio

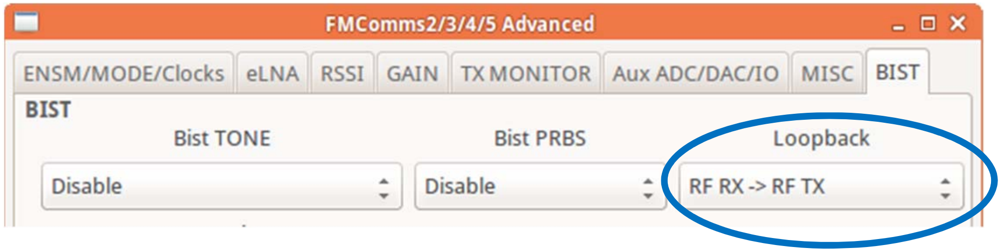
Let's first scan the FM spectrum to see what stations we can pick up.  Set:
RF BW to 18MHz
Sample rate to 30.72MSPS
RX_LO to 97.9 MHz
Gain control to Slow Attack

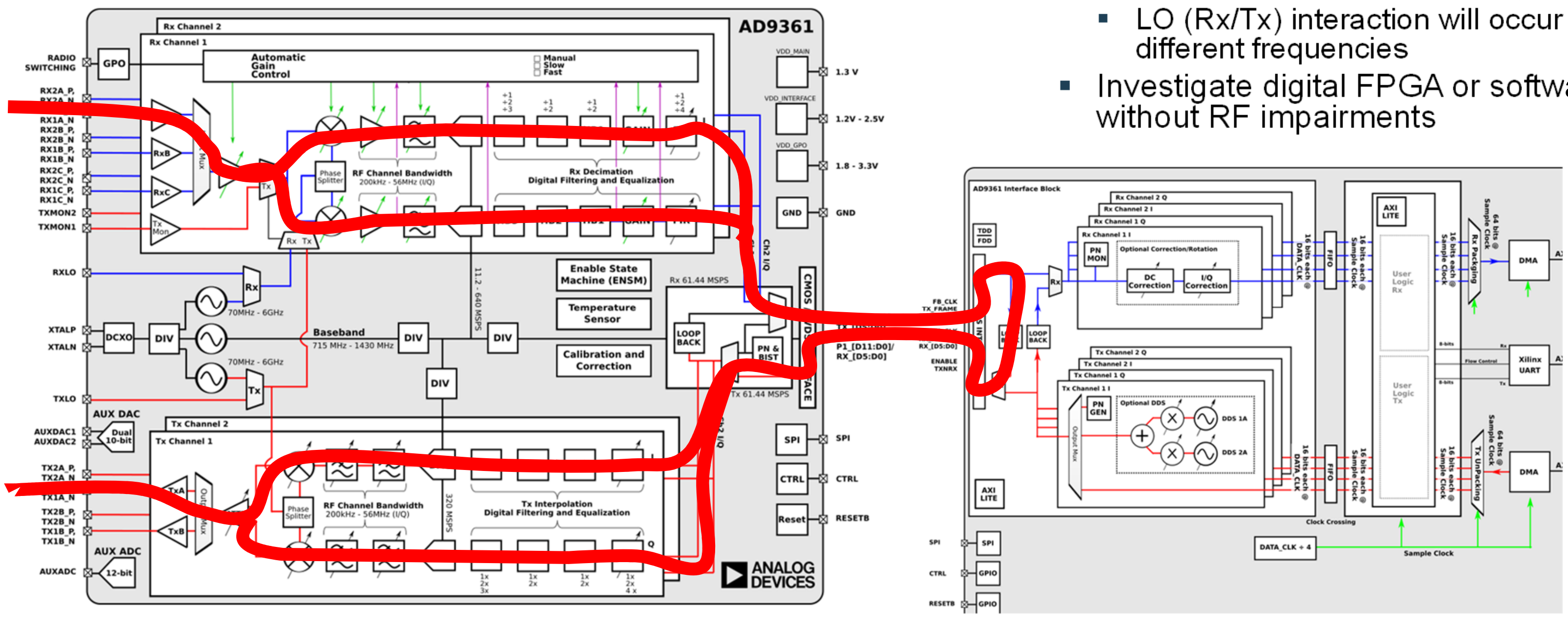
Set TX1 attenuation to 89 dB. This will quiet out TX1 so it doesn't interfere with our station selection.

Plot the Frequency Domain. Right Click on the plot and turn on peak markers.



# Loopback Paths




- Reuse the loopback paths for testing and development
  - Investigate hardware RF issues without software or FPGA interaction
    - Signal still digitalized, still goes through filters
    - will see RF impairments due to AD9361 setup
    - Output will be baseband copy of input
    - LO (Rx/Tx) interaction will occur if the same frequency – use different frequencies
  - Investigate digital FPGA or software algorithm issues without RF impairments

# Pluto Lab 3:  Rx and Tx FM Radio

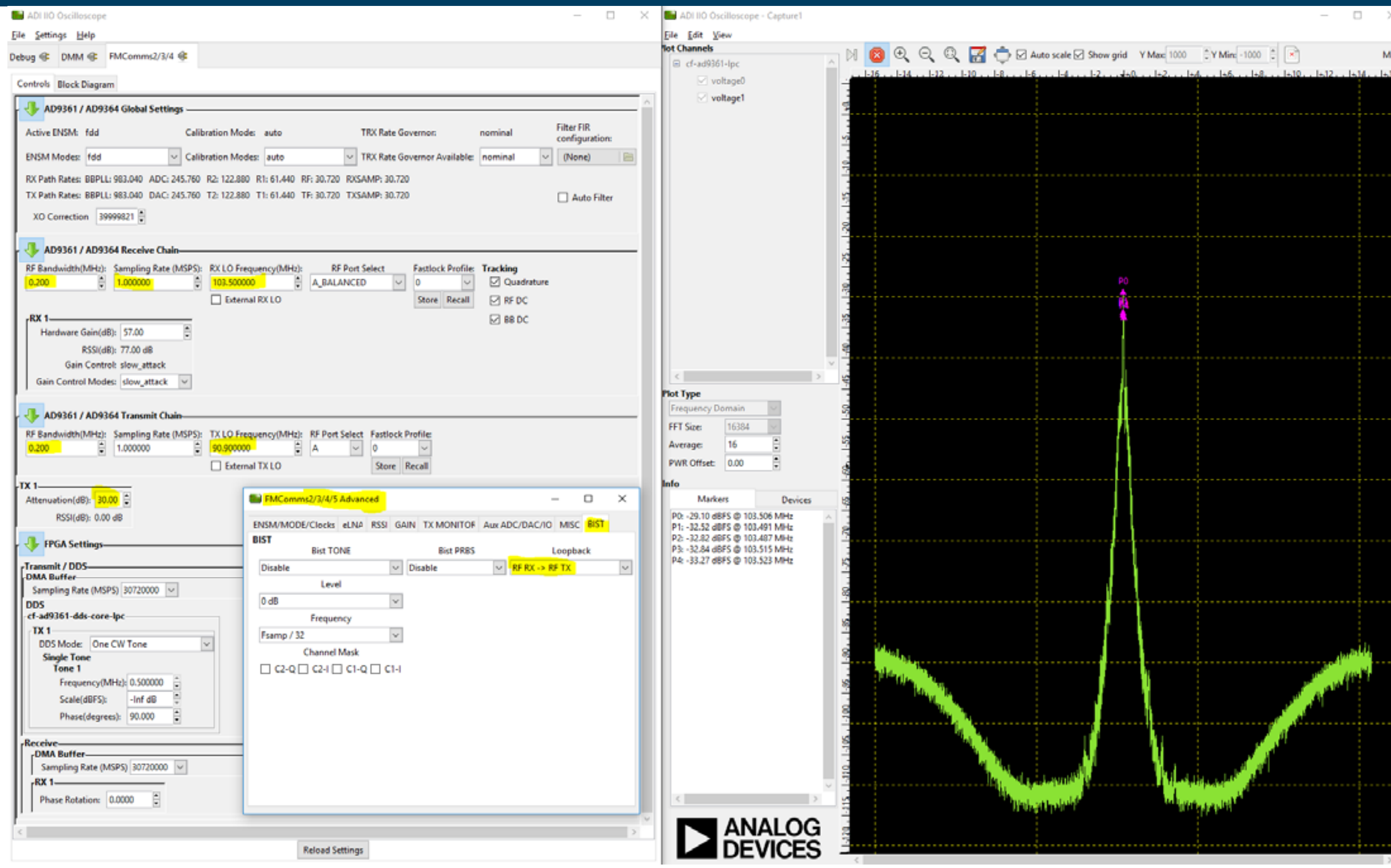
Now set RX_LO to a strong station that we saw on the previous slide (103.5 MHz in this example).

Set Rx RF BW to 200kHz and sampling to 1MSPS

Now, let's transmit on some other FM frequency.
 - If you have a radio, tune it to a spot where no strong signal was observed. (90.9MHz for example this).  You should hear static or weak radio stations.
- Now set the TX to 90.9MHz (or your selected station) and attenuation to 89 dB.

Go to FMComms Advanced Tab→BIST→Loopback→RF RX to RF TX

Now decrease the TX attenuation until your radio picks up the re-broadcasted station.  Something around 20 or 30 dB should work well.  There's no need to make it stronger than it needs to be!



# Pluto Lab 4:  Transmit FM Radio at 2.4 GHz!

► Consider how you could use 2 Pluto’s to send the FM Radio Station: