SDR MIMO-OFDM Implementation

[Current Dependencies](#_stp1ytk92n1j)

[Required](#_rxpshgsw8exj)

[Recommended](#_c69ylctrzfoh)

[Hardware](#_7wmecxyjn25t)

[Installation Notes from Scratch](#_wv0qe5mmclv3)

[HostPC Ubuntu 22.04 Setup](#_kv2or67vzh0p)

[Performance Tricks](#_ywvdtvbd110y)

[Installing UHD from Source (Branch checkout)](#_yurdsfrbpq6f)

[Installing GnuRadio from Source](#_p4fumwtvn6l8)

[Installing Virtual Box to Control LO Board](#_osnbenjm3ysk)

[Uninstalling UHD](#_3y45o5e15koe)

[Uninstalling GnuRadio [No make uninstall implemented ⇒ Manual uninstall required]](#_yv80u84crvft)

[Installing QT Creator for GUI App](#_mdhaks740e2y)

[Installing DPDK 18.11 from Source [optional]](#_2kx6haij6tv6)

[DPDK Configuration (Not installed maybe needed in future)](#_hw5a5brrsnlz)

[USRP Calibration Scripts](#_9u12dl3st215)

[Ethernet Config](#_kxfo9zj9c3ds)

[SHUTDOWN USRPs](#_wr9s3xwr0w02)

[Deleting previous ssh keys](#_rd9tulpipp75)

[Benchmarking USRP Data Streaming over Ethernet](#_e33r9c76h0j3)

[Updating Boot Image of USRP N32x (SD Card)](#_2g94lpr3i4f)

[Updating FPGA Image of USRP N32x (via Ethernet)](#_n3i4x8f5pt07)

[DSP Block Development for GNURadio (Out of Tree Modules)](#_5mohuyfcgjxr)

[Editing Blocks](#_evfpvp3yxqns)

[Adding RFNoC Block to FPGA [optional]](#_ojictzd8ctlu)

[Visual Studio Code Config](#_igaxsrz9gwot)

[tasks.json](#_ms2rzoeu3wz6)

[launch.json](#_d1yyo5w9bbf4)

[Host PC Issues with Ubuntu 22.04 (After clean OS install)](#_p7wc722wsi3c)

[Renaming All Files in a Directory (Recursively for subdirectories)](#_of64tufu79zc)

## 

## Current Dependencies

### Required

* Ubuntu 22.04
  + To install Wi-Fi drivers
    - https://askubuntu.com/questions/1407357/rtl8821ce-driver-not-working-on-ubuntu-22-04
* UHD 4.1.0.5
* GnuRadio v3.8.5.0
  + Don't forget to use correct branch version —> git checkout maint-3.8
  + https://github.com/bastibl/gr-foo
  + https://github.com/kit-cel/gr-radar/tree/maint-3.8
  + gr-ettus (for RFNOC)
    - git checkout e3a6e8008d945847ec1ec4d0f50267dc8d3f8dbe
* QT Creator
* EIGEN3 (libeigen3-dev)
* QT5
* USRP SD Card, Linux and FPGA Image versions should match UHD version at Host PC
* Virtual Box with Windows 10 installation to control LO Board
  + ACE Software in Windows 10
  + https://askubuntu.com/a/872206

### Recommended

* VS Code as IDE for block development in C++ and Python
  + Syntax highlighting and additional extension support
  + Provides quick build and install templates
  + Some level of debugging is supported

## Hardware

* 2 x USRP N320
* 1 x USRP N321
* CDA-2990 Clock Distribution
* Host PC
  + Gigabyte Z690 UD DDR4 [Motherboard]
  + Intel i9 12900K
  + Nvidia GeForce RTX 3080
  + [NIC] 2 x Intel X520-DA2 [PCIe 2.0 x 8]
  + [NIC] Intel X710-DA2 (from Lenovo) [works better than X520] [PCIe 3.0 x 8]

## 

## Installation Notes from Scratch

### HostPC Ubuntu 22.04 Setup

* osuwireless Setup
  + openssl version -d
  + sudo subl /usr/lib/ssl/openssl.cnf
  + https://askubuntu.com/a/1405397

### Performance Tricks

* for ((i=0;i<$(nproc);i++)); do sudo cpufreq-set -c $i -r -g performance; done
* cat /sys/devices/system/cpu/cpu\*/cpufreq/scaling\_governor
* watch -n 1 cat /proc/interrupts
  + watch 'cat /proc/interrupts | tail -n100'
* sudo systemctl stop irqbalance.service
* http://glenewhittenberg.blogspot.com/2016/03/intel-x520-da2-performance-tuning-for.html
* https://www.kernel.org/doc/Documentation/networking/ixgb.txt

### Installing UHD from Source (Branch checkout)

* go to home
* git clone https://github.com/EttusResearch/uhd.git
* cd uhd
* git checkout UHD-4.1
* git submodule update --init --recursive
* Follow <https://files.ettus.com/manual/page_build_guide.html>

### Installing GnuRadio from Source

* [https://wiki.gnuradio.org/index.php?title=InstallingGR#For\_GNU\_Radio\_3.8\_or\_Earlier](https://wiki.gnuradio.org/index.php?title=InstallingGR" \l "For_GNU_Radio_3.8_or_Earlier)
* Add following to ~/.bashrc
  + export PYTHONPATH=/usr/local/lib/python3/dist-packages:/usr/local/lib/python3/site-packages:$PYTHONPATH
  + export LD\_LIBRARY\_PATH=/usr/local/lib:$LD\_LIBRARY\_PATH
* OR
  + echo 'export PYTHONPATH=/usr/local/lib/python3/dist-packages:usr/local/lib/python2.7/site-packages:$PYTHONPATH' >> ~/.bashrc
  + echo 'export LD\_LIBRARY\_PATH=/usr/local/lib:$LD\_LIBRARY\_PATH' >> ~/.bashrc
  + echo 'export PYTHONPATH=/usr/local/lib/python3/dist-packages:usr/local/lib/python2.7/site-packages:$PYTHONPATH' >> ~/.profile
  + echo 'export LD\_LIBRARY\_PATH=/usr/local/lib:$LD\_LIBRARY\_PATH' >> ~/.profile
* Add following line to gnuradio/gnuradio-runtime/lib/flat\_flowgraph.cc
  + #define GR\_FIXED\_BUFFER\_SIZE (512\* (1L << 10))
  + Note: recompile GNU-Radio after editing.

### Installing Virtual Box to Control LO Board

* <https://www.virtualbox.org/wiki/Linux_Downloads>
* Install extension pack
  + https://www.virtualbox.org/wiki/Downloads
* sudo adduser $USER vboxusers

#### Uninstalling UHD

* go to uhd/host/build
* sudo make uninstall [This should work]

#### Uninstalling GnuRadio [No make uninstall implemented ⇒ Manual uninstall required]

* go to gnuradio/build
* xargs rm < install\_manifest.txt

## 

## Installing QT Creator for GUI App

* sudo apt install qtcreator

## Installing DPDK 18.11 from Source [optional]

* make config T=x86\_64-native-linuxapp-gcc
* In dpdk/build/.config change CONFIG\_RTE\_BUILD\_SHARED\_LIB=n to =y
* In dpdk/config/common\_base change CONFIG\_RTE\_BUILD\_SHARED\_LIB=n to =y

### DPDK Configuration (Not installed maybe needed in future)

* sudo modprobe vfio-pci
* sudo dmesg
* Bind DPDK-compatible driver to 10G NIC
  + sudo ifconfig enp1s0f1 down
  + sudo /usr/bin/dpdk-devbind.py -b vfio-pci enp1s0f1
  + sudo /usr/bin/dpdk-devbind.py -s
* sudo subl /root/.uhd/uhd.conf [deprecated]
* sudo subl /root/.config/uhd.conf

## USRP Calibration Scripts

* uhd\_cal\_rx\_iq\_balance --verbose --subdev 'A:0'
* uhd\_cal\_tx\_iq\_balance --verbose --subdev 'A:0'
* uhd\_cal\_tx\_dc\_offset --verbose --subdev 'A:0'
* uhd\_cal\_rx\_iq\_balance --verbose --subdev 'B:0'
* uhd\_cal\_tx\_iq\_balance --verbose --subdev 'B:0'
* uhd\_cal\_tx\_dc\_offset --verbose --subdev 'B:0'

## Ethernet Config

* sudo ifconfig eth0 mtu 9000
* Display current parameters
  + ethtool -c enp7s0f1
* Increase the ring buffer for each interface:
  + sudo ethtool -G <interface> tx 4096 rx 4096

## SHUTDOWN USRPs

* ssh root@192.168.10.2
* shutdown -h now

### Deleting previous ssh keys

* + ssh-keygen -f "/home/workstation/.ssh/known\_hosts" -R "192.168.10.2"

## Benchmarking USRP Data Streaming over Ethernet

* /usr/local/lib/uhd/examples/benchmark\_rate --args "addr=192.168.120.2,master\_clock\_rate=200e6" --duration 10 --channels "0" --rx\_rate 200e6 --rx\_subdev "A:0"
* /usr/local/lib/uhd/examples/benchmark\_rate --args "addr=192.168.120.2,master\_clock\_rate=200e6" --duration 10 --channels "0,1" --rx\_rate 100e6 --rx\_subdev "A:0 B:0"
* /usr/local/lib/uhd/examples/benchmark\_rate --args "addr=192.168.120.2,master\_clock\_rate=200e6" --duration 10 --channels "0,1" --tx\_rate 100e6 --tx\_subdev "A:0 B:0"

## 

### Updating Boot Image of USRP N32x (SD Card)

<https://kb.ettus.com/Writing_the_USRP_File_System_Disk_Image_to_a_SD_Card>

* usr/include/uhd contains the current UHD version in the SD Card
* sudo uhd\_images\_downloader -t sdimg -t n3xx
* Unmount all partitions of the SD Card
* sudo bmaptool copy <IMAGE> <SD\_CARD\_DEV\_NAME> --bmap <IMAGE BMAP (\*.sdimg.bmap)>
  + sudo bmaptool copy /home/workstation/images/usrp\_n3xx\_fs.sdimg /dev/sdc --bmap /home/workstation/images/usrp\_n3xx\_fs.sdimg.bmap
  + sudo bmaptool copy /usr/local/share/uhd/images/usrp\_n3xx\_fs.sdimg /dev/sdc --bmap /usr/local/share/uhd/images/usrp\_n3xx\_fs.sdimg.bmap

/usr/local/share/uhd/images

* sync
* remove SD Card

### Updating FPGA Image of USRP N32x (via Ethernet)

[https://kb.ettus.com/USRP\_N300/N310/N320/N321\_Getting\_Started\_Guide#Network\_Mode\_FPGA\_Image\_Update](https://kb.ettus.com/USRP_N300/N310/N320/N321_Getting_Started_Guide" \l "Network_Mode_FPGA_Image_Update)

* sudo uhd\_images\_downloader
* uhd\_image\_loader --args "type=n3xx,addr=192.168.10.2,fpga=HG"

## DSP Block Development for GNURadio (Out of Tree Modules)

<https://wiki.gnuradio.org/index.php/OutOfTreeModules>

* mkdir build, cd build, cmake.. , make , sudo make install

## Editing Blocks

* When a header file in ./include is modified, the old header files in /usr/local/include/{library-name}/ should be removed to prevent compiler error (argument error).
  + e.g., sudo rm -rf /usr/local/include/mimo\_ofdm\_jrc
  + sudo rm -rf /usr/local/lib/python3/dist-packages/mimo\_ofdm\_jrc
* When inputs, outputs, and parameters of a block are modified, build directory should be cleaned and cmake should be run again.

### Adding RFNoC Block to FPGA [optional]

* <https://kb.ettus.com/Getting_Started_with_RFNoC_in_UHD_4.0>
* Already Available RFNoC blocks
  + home/<user>/uhd/fpga/usrp3/lib/rfnoc/blocks/
  + /home/hostpc-usrp/uhd/host/include/uhd/rfnoc/blocks/
* go to home/<user>/uhd/fpga/usrp3/top/n3xx/
* cp n320\_rfnoc\_image\_core.yml n320\_rfnoc\_image\_with\_moving\_average.yml
* rfnoc-example/icores/x310\_rfnoc\_image\_core.yml
* home/<user>/uhd/host/examples/rfnoc-example
* rfnoc\_image\_builder -y n320\_rfnoc\_image\_with\_moving\_average.yml -t N320\_XG

## Visual Studio Code Config

### tasks.json

{

"version": "2.0.0",

"tasks": [

{

"label": "Build Legion",

"type": "shell",

"command": "cd ${workspaceFolder}/build;./auto\_build.sh",

"group": {

"kind": "build",

"isDefault": true

},

// "options": {

// "cwd": "${workspaceFolder}/build/"

// },

},

{

"type": "cppbuild",

"label": "C/C++: clang build active file",

"command": "/usr/bin/clang",

"args": [

"-fdiagnostics-color=always",

"-g",

"${file}",

"-o",

"${fileDirname}/${fileBasenameNoExtension}"

],

"options": {

"cwd": "${fileDirname}"

},

"problemMatcher": [

"$gcc"

],

"group": "build",

"detail": "compiler: /usr/bin/clang"

}

]

}

### launch.json

{

// Use IntelliSense to learn about possible attributes.

// Hover to view descriptions of existing attributes.

// For more information, visit: https://go.microsoft.com/fwlink/?linkid=830387

"version": "0.2.0",

"configurations": [

{

"name": "(gdb) Launch",

"type": "cppdbg",

"request": "launch",

"program": "/usr/bin/python3",

"args": ["-u","/home/workstation/MIMO\_OFDM\_2022/Alignment/usrp\_alignment\_sync\_trx.py"],

"stopAtEntry": false,

"cwd": "${workspaceFolder}",

"environment": [],

"externalConsole": false,

"MIMode": "gdb",

"setupCommands": [

{

"description": "Enable pretty-printing for gdb",

"text": "-enable-pretty-printing",

"ignoreFailures": true

}

]

},

]

}

## Host PC Issues with Ubuntu 22.04 (After clean OS install)

* WiFi Driver
  + sudo apt-get install rtl8821ce-dkms
* Connecting to osuwireless (need to fix security protocols in OpenSSL config file
  + https://askubuntu.com/a/1405397
* https://discourse.ubuntu.com/t/22-04-nvidia-drivers/28072
* https://linuxconfig.org/how-to-enable-disable-wayland-on-ubuntu-22-04-desktop
* https://askubuntu.com/questions/1403854/cant-use-wayland-with-nvidia-510-drivers-on-ubuntu-22-04-lts

### Renaming All Files in a Directory (Recursively for subdirectories)

* <https://askubuntu.com/questions/227410/replace-all-colons-from-filenames-with-terminal>
* find **{path}** -type f -exec rename 's|**{find}**|**{replace}**|g' \*.webm -v -n {} \;
  + find /home/hostpc-usrp/Dropbox/experiments/ -type f -exec rename 's|:|-|g' \*.webm -v -n {} \;
  + find . -type f -exec rename 's|:|-|g' \*.webm -v -n {} \;
* -n only shows what will happen → remove -n to execute rename