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Analog LMR to MCPTT Communications

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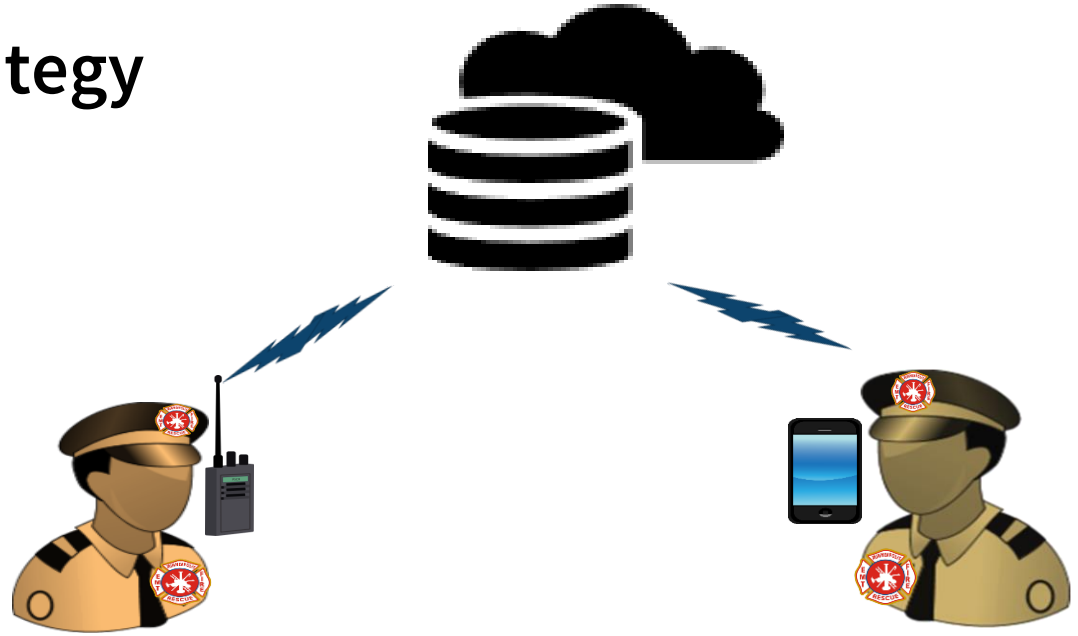
*** Please note, unless mentioned in reference to a NIST Publication, all information and data presented is preliminary/in-progress and subject to change**

INTRODUCTION

- PSCR LMR to Broadband (LTE/5G) Focus Areas
- Current Status of LMR to Broadband Capabilities and Development
- PSCR's LMR to Broadband Strategy
- Current Research Project
- Recognized Challenges



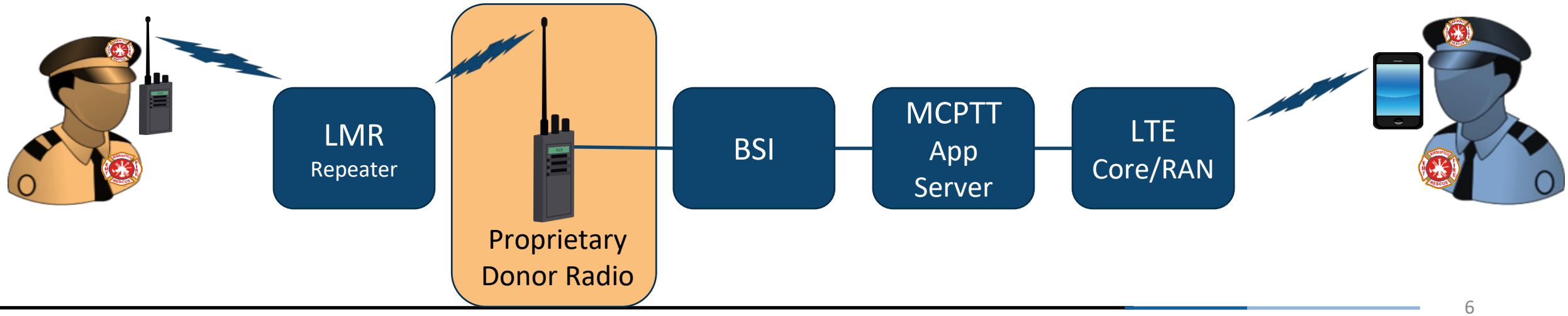
PSCR LMR TO BROADBAND PROJECTS

- Current PSCR LMR to Broadband Interworking Projects
  - IWF Tester Procurement (Jon Cook)
  - IWF Procurement (Jon Cook)
  - LMR to EPTT Interworking (Tim Thompson)
  - RoIP based LMR to Broadband(Bradshaw, Walton)
  - Analog LMR to MCPTT (Cook, O'Dell, Walton)

** More details about these other projects in the "LMR to Broadband Research and Funding Strategy" Session**

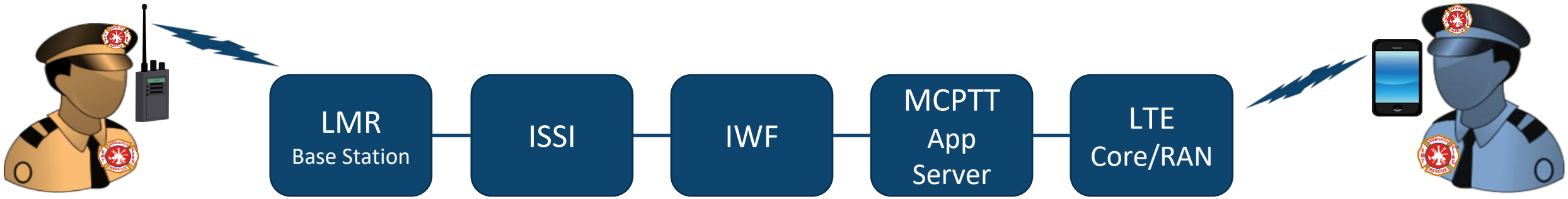
STATUS OF LMR TO BROADBAND CAPABILITIES AND DEVELOPMENT

- Bridging System Interfaces (Radio Over IP <ROIP>)
  - Originally designed for non-ISSI LMR systems
  - Requires donor radios or a system-level connection
  - Proprietary interfaces
    - Initial ROIP designs were proprietary, this was remedied via BSI
    - May include 3GPP IWF (DHS Small Business Innovation Research) interface



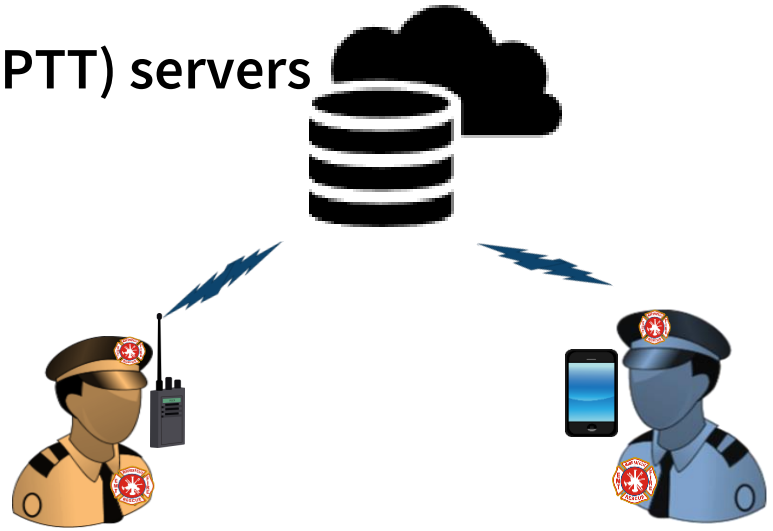
STATUS OF LMR TO BROADBAND CAPABILITIES AND DEVELOPMENT

- Inter-RF Subsystem Interface (ISSI)
  - Originally designed for P25 to P25 system interoperability
  - Focus of government and industry for LMR to broadband
  - Solution for compatible digital systems(newer P25)
  - 3GPP interface compliant through Interworking Function (IWF)



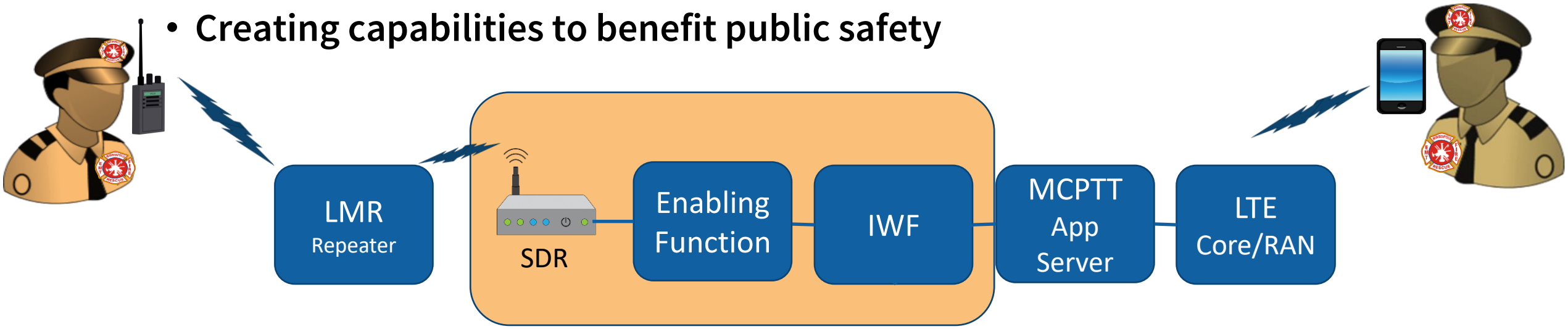
A MISSING COMBINATION

- Support of analog FM LMR via Software Defined Radio (SDR)
- Air-Interface (RF) based
  - Does not require special interface to existing systems
- Affordable
  - No donor radios required
  - No highly proprietary solutions
- 3GPP Standards-Based
  - Compatible with IWF and Mission Critical Push-to-Talk (MCPTT) servers
  - Does not require middleware service
  - No special apps
- Open Source
  - Competitive environment for companies



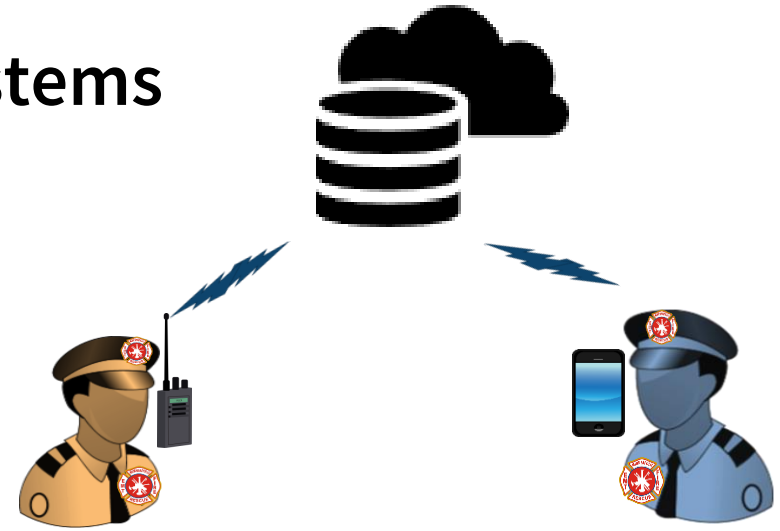
PSCR'S LMR TO BROADBAND PHILOSOPHY

- Research Objectives
  - Research and prototype Software Defined Radio (SDR) solutions
    - "LTE core talks to the tower like it's a radio"
    - Focus on analog FM and non-ISSI compatible P25
  - Determine if existing IWF and MCPTT capabilities are sufficient
    - Target efforts to fill gaps
  - 3GPP Standards involvement and contributions
  - Creating capabilities to benefit public safety



PSCR'S LMR TO BROADBAND PATH

- Overall Goal: Fill the Technology Gaps
  - ISSI is being addressed by industry
  - ROIP and other custom solutions exist
- Current Project
    - Basic floor control
    - Audio passthrough
- Research to support widely deployed Analog Systems
- Next Steps
    - Full duplex RTP audio on single channel
    - GNURadio development



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PSCR LMR to Broadband Passthrough Development

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ANALOG PSCR PASSTHROUGH SOLUTION

Scope: Create a proof of concept conventional analog LMR to MCPTT LTE interoperability technology

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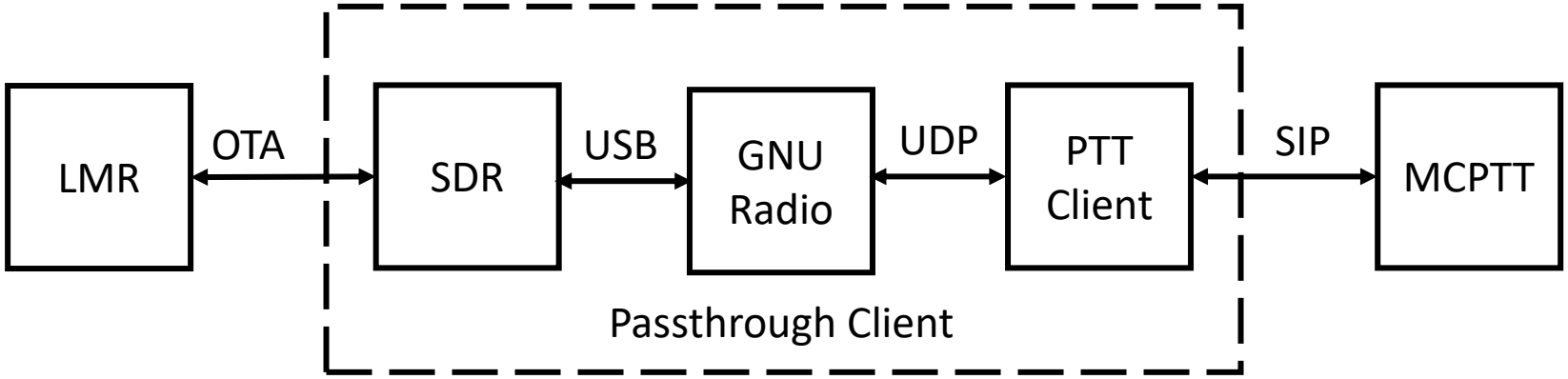
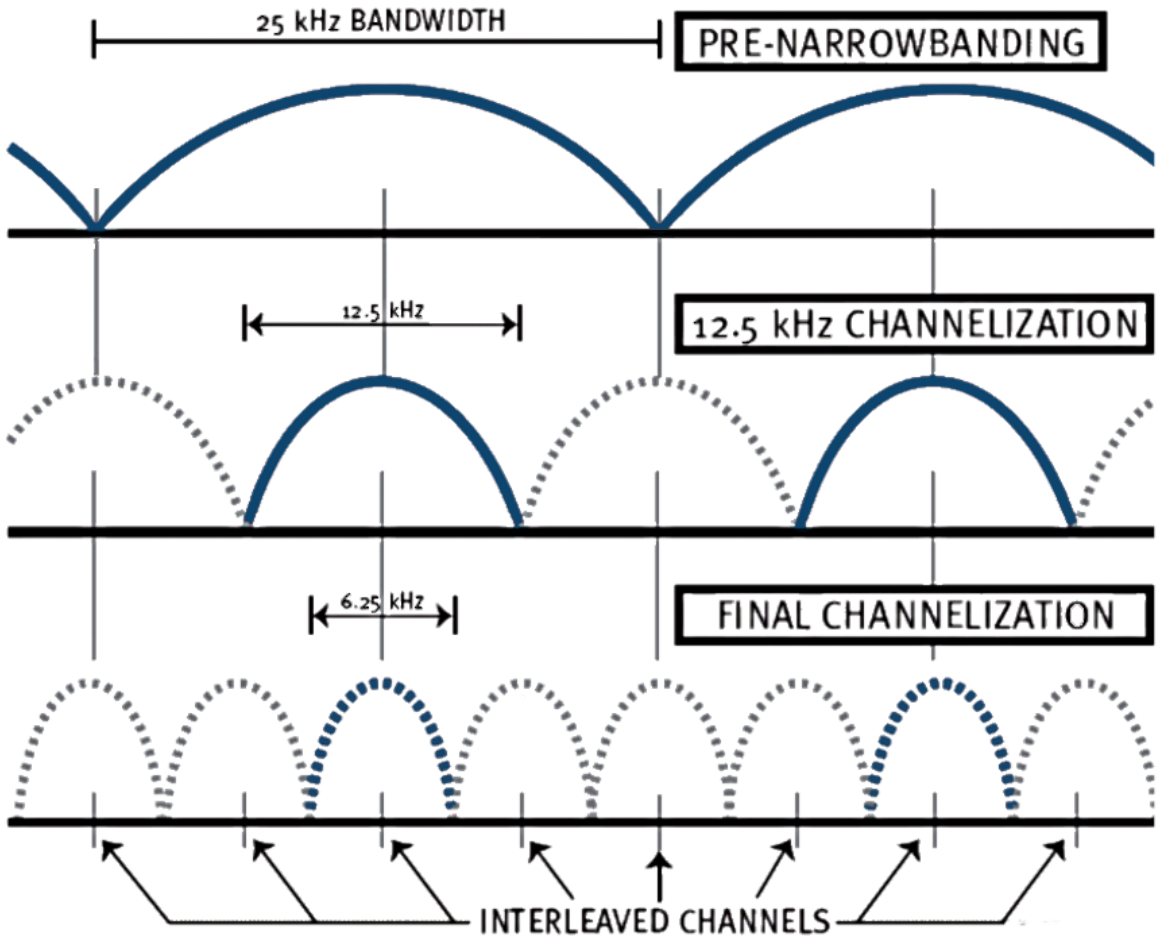


LMR

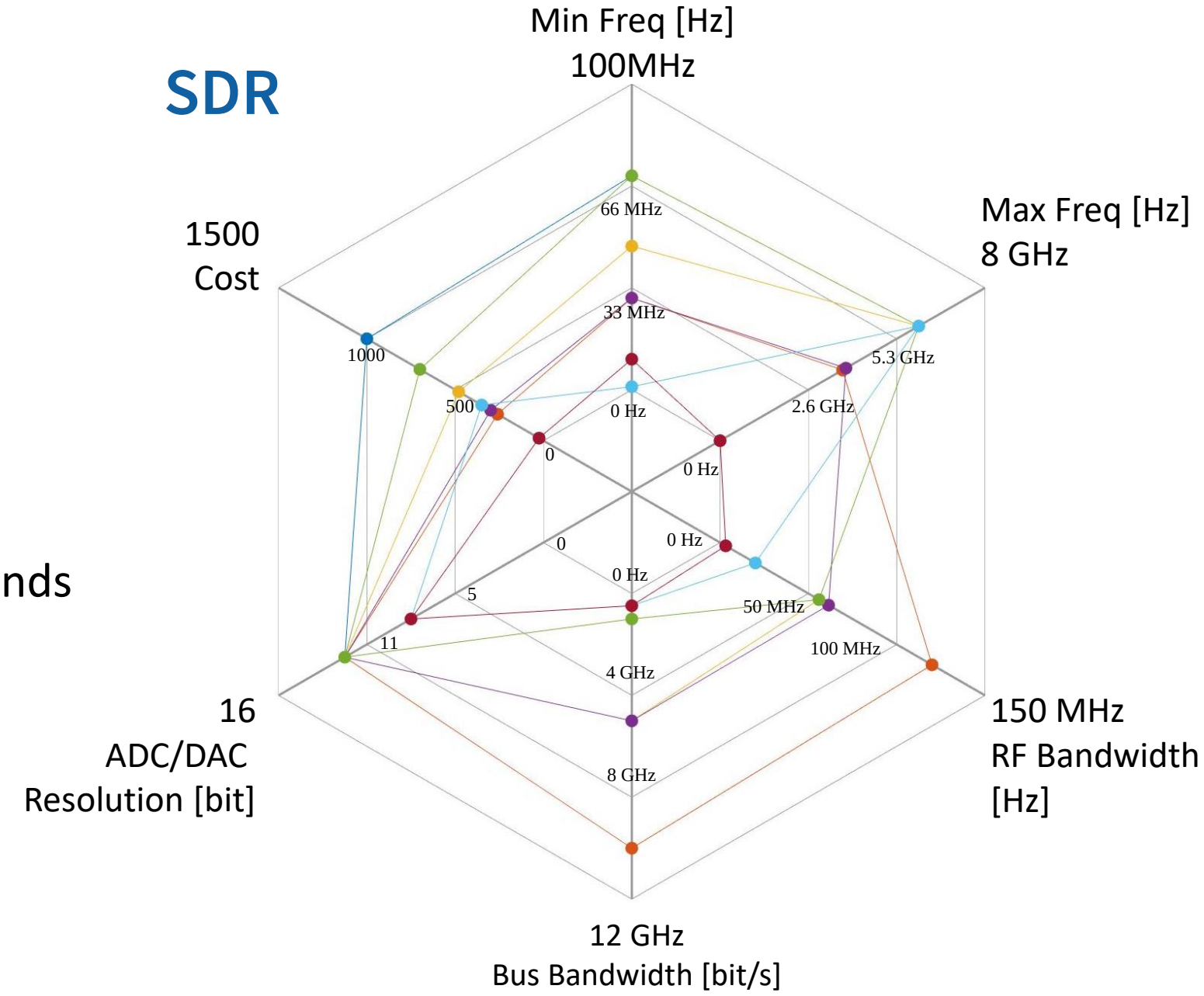
- Defining conventional analog FM LMR
  - Simplex / duplex operation
  - No digital capability
  - No vocoder
- Channel bandwidth of 12.5 kHz or less
- Commonly in VHF / UHF spectrum



SDR

- Data pulled from GNURadio.org

  SDR hardware list
- High availability
- Relatively low cost
- Support public safety Comms bands



B2xx
XTRX-CS
BladeRF2
LimeSDR
New Horizons
Hack RF One
RTL-SDR

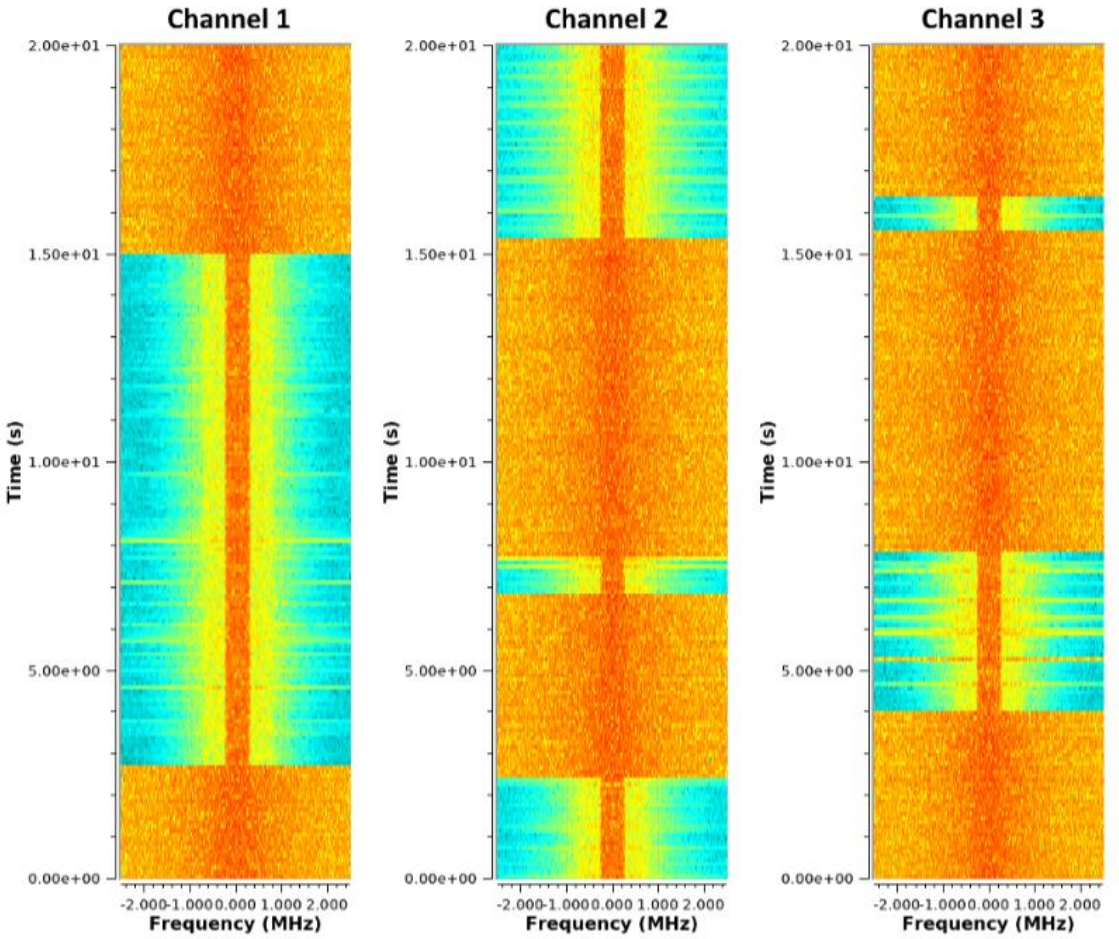
SDR-Legend

SOFTWARE DEFINED RADIO HARDWARE

- Multiple models available at various price points
  - Some SDR options are capable of running GNURadio flows natively
- USRP B210 used for this prototype
  - 70 MHz - 6GHz transceiver

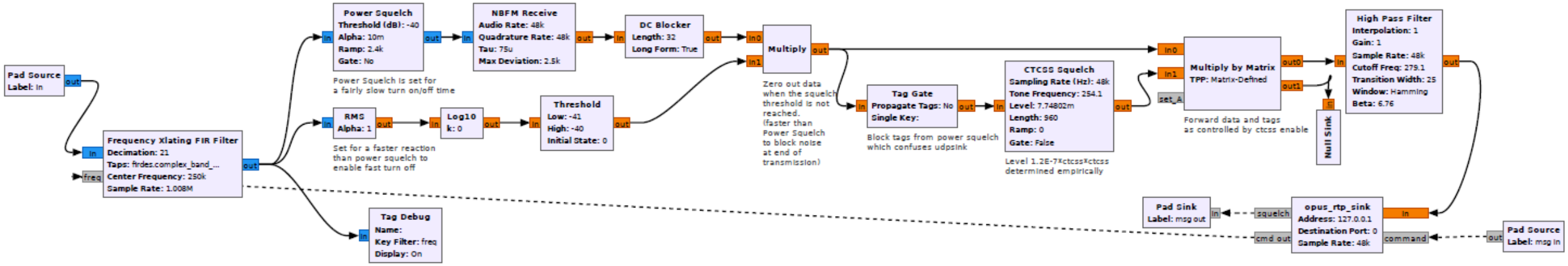
GNURadio

- Process data sampled by SDR
  - Demodulate / modulate
- Real time operation
  - Command burst Tx of SDR
- Open-source software

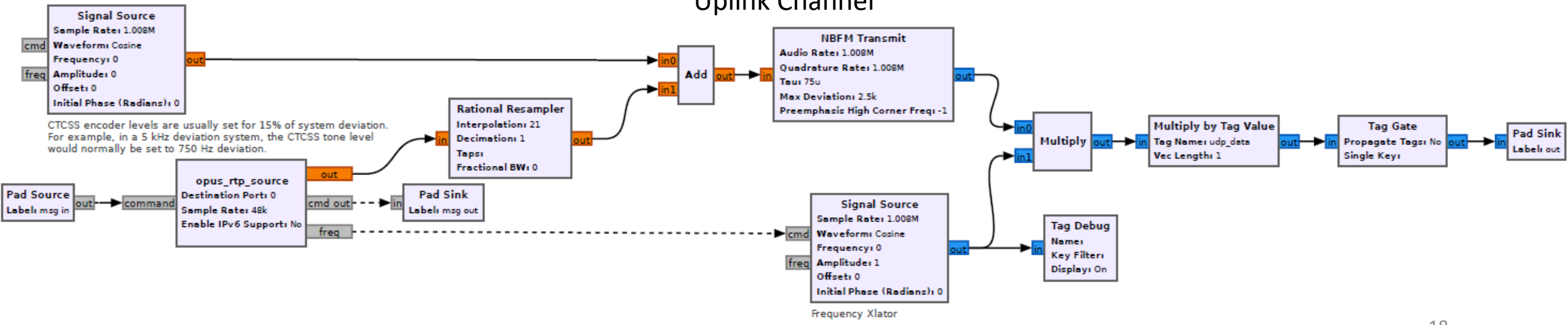


GNURadio

Downlink Channel

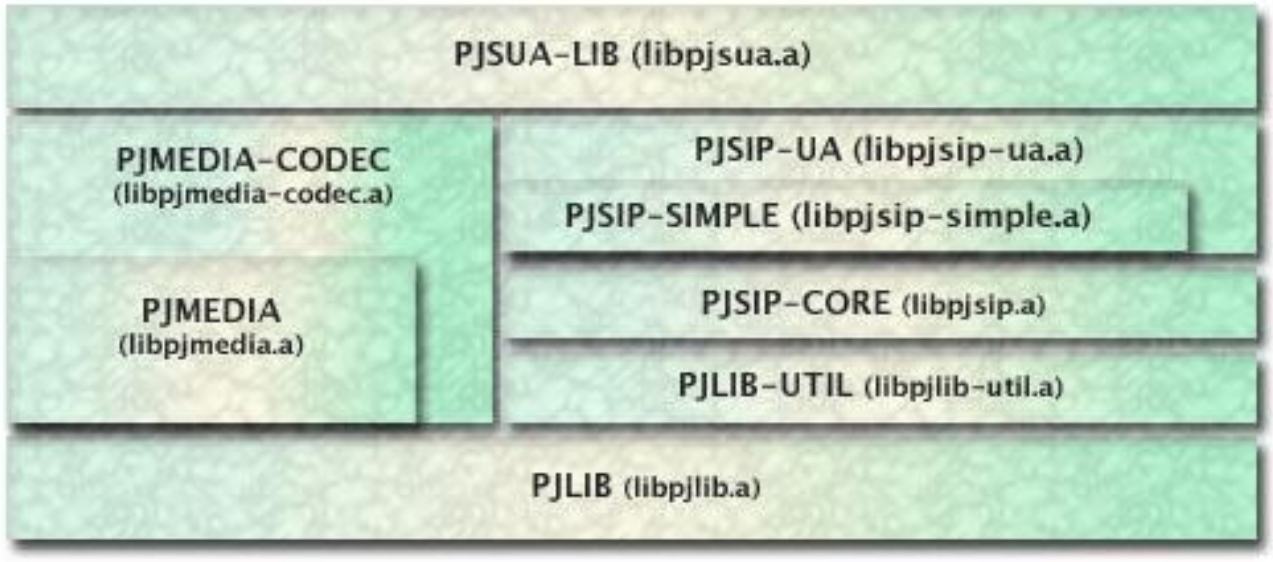


Uplink Channel



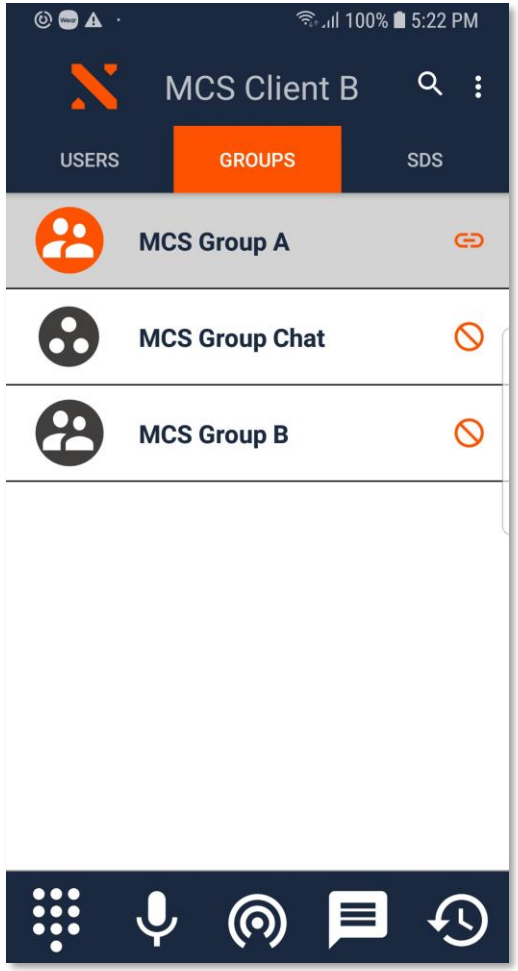
PJSUA

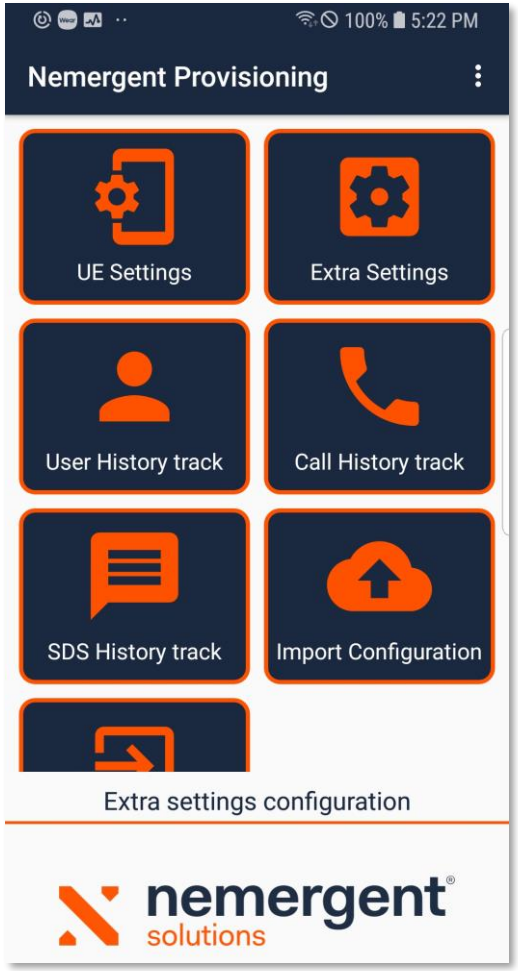
- Transport protocol: RTP, UDP, SIP
- AMR-NB/WB and Opus codec support
- AKA and Digest encryption
- Open-source software



MCPTT-BROADBAND

- MCX Application Server
  - MCx: PTT, Data, and Video
  - Operations & Maintenance GUI
- MCx Client/Non-MCx Client
- IWF vs Enabler





UP NEXT

GNU Analog FM Radio Development

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DESIGN PHILOSOPHY

- Open-Source Software
  - GNURadio
    - GNURadio is a free & open-source toolkit for software radio
    - Allows for custom out-of-tree (OOT) modules
  - PJSIP
    - PJSIP is a free and open-source multimedia communication library written in C language implementing standard based protocols such as SIP, SDP, RTP, STUN, TURN, and ICE.
- Commercially Available Software Designed Radio
  - Universal Software Radio Peripheral (USRP™) family of products

DESIGN DETAILS

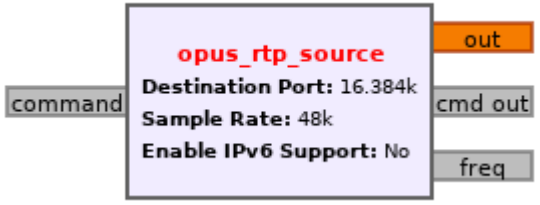
- GNURadio Hierarchical Blocks
  - Each Tx/Rx flowgraph is built from generic and custom blocks
    - Individual parameters per Tx/Rx block for carrier frequency and CTCSS frequency
    - Tx and Rx flowgraphs used as individual blocks in higher level flowgraph
  - Tx and Rx blocks combined in transceiver array flowgraph
  - Transceiver array flowgraph used as a block in top level flowgraph
  - Number of RF channels limited by processing power of host computer
- Custom Out-of-Tree GNURadio Blocks Developed by PSCR
  - SIP signaling block interfaces with PJSIP
  - RTP blocks send and receive opus encoded voice data
  - LED block to display registration, call, and floor status

SIP SIGNALING BLOCK

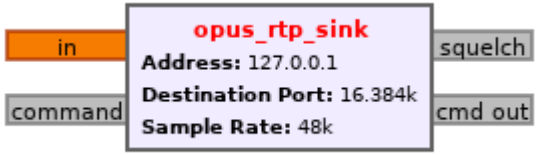
- Set channel information for each RF channel
  - Channel frequency offset from SDR center frequency
  - CTCSS frequency (zero if not used)
- Registers each RF channel to MCPTT Server as a separate user
- Manages RTP Ports used for voice traffic to/from MCPTT Server
- Requests floor when Receiver detects activity on an RF channel
- Responds to floor commands from MCPTT Server
- Updates LED Blocks to show channel status

RTP BLOCKS

- Source Block
  - Receives voice traffic from MCPTT server using opus encoding
  - Converts opus encoded data into voice samples
  - Provides tags to indicate start and end of transmission



- Sink Block
  - Notifies SIP signaling block when squelch/CTCSS is detecting LMR signal
  - Converts voice samples into opus encoded data
  - Sends encoded data to MCPTT server



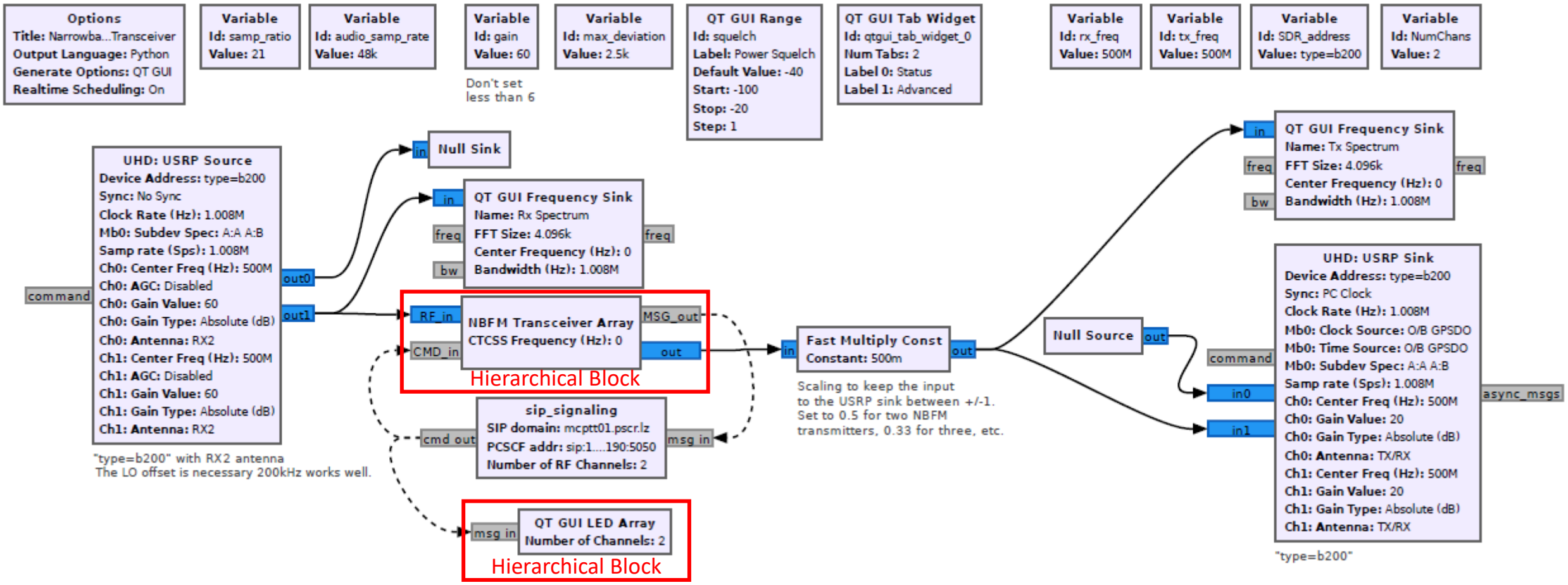
VOCODING

- Analog voice is converted to Digital Data through a process called Vocoding
  - RFC 3551 defines the vocoders that can be used with RTP
  - Many vocoders exist with tradeoffs between quality and bitrate
  - Some vocoders are open source and others require a license
- Vocoder requirements
  - Open source to eliminate the cost of a vocoder license
  - High-quality audio with reasonable bitrate
  - Vocoder must be supported by MCPTT server

VOCODER SELECTION

- Several Vocoders Were Considered
  - L16 – simple 16 bit analog to digital conversion
    - Native to GNURadio
    - Not supported by MCPTT server
  - AMBE – vocoder used by P25 LMR
    - Expensive license required
  - AMR-WB – vocoder used by 3GPP
    - Moderately expensive license required
  - PCMA, PCMU - narrowband audio codec designed for use in telephony
    - Audio quality would be reduced
  - Opus – efficient codec developed by the Xiph.Org Foundation and standardized by the Internet Engineering Task Force
    - Open source (free)
    - Supported by MCPTT server
    - Good voice quality at fairly low bitrate

EIGHT CHANNEL GNURADIO FLOW DIAGRAM (TOP LEVEL)



EIGHT CHANNEL GNURADIO TRANSCEIVER ARRAY

Options
Title: NBFM Transceiver Array
Output Language: Python
Generate Options: Hier Block
Category: [GRC Hier Blocks]

Parameter
Id: aud_to_rf
Label: Sample R... Rate ratio
Value: 21
Type: Int

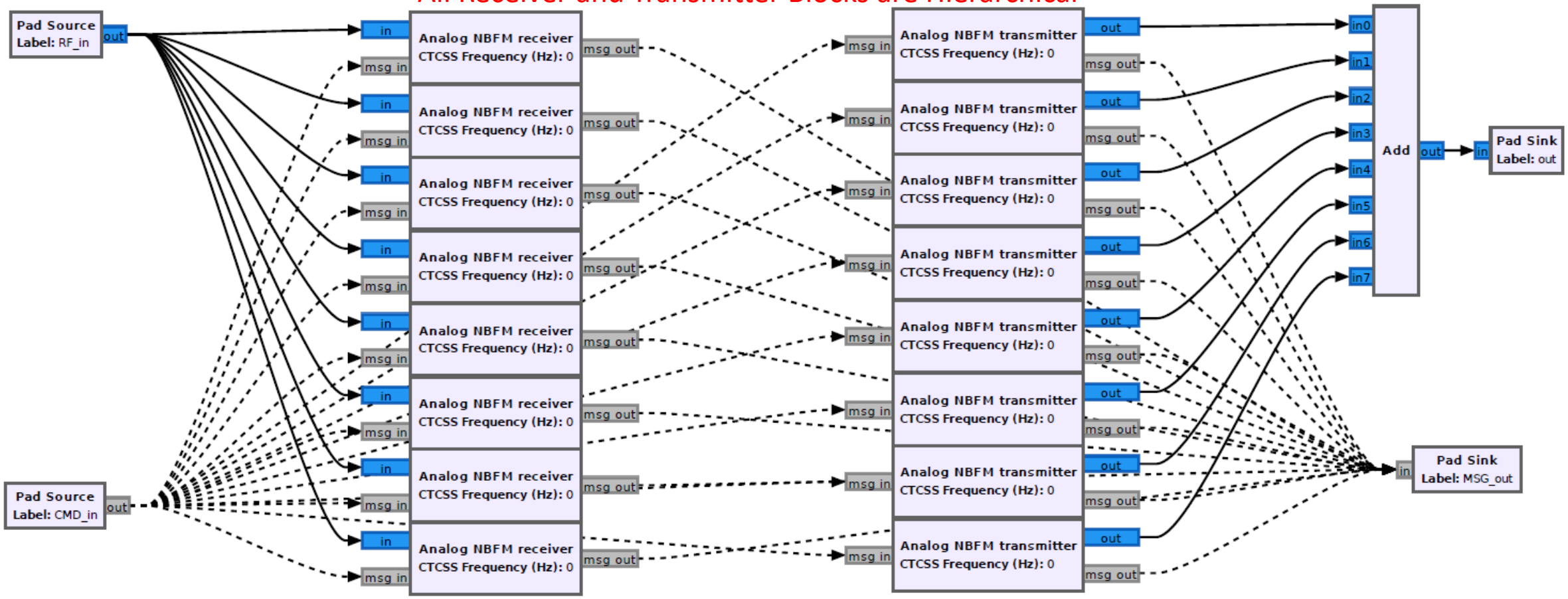
Parameter
Id: Audio_samp_rate
Label: Audio Sample Rate
Value: 48k
Type: Int

Parameter
Id: Max_deviation
Label: Maximum Deviation (Hz)
Value: 2.5k
Type: Float

Parameter
Id: ctcss
Label: CTCSS Frequency (Hz)
Value: 0
Type: Float

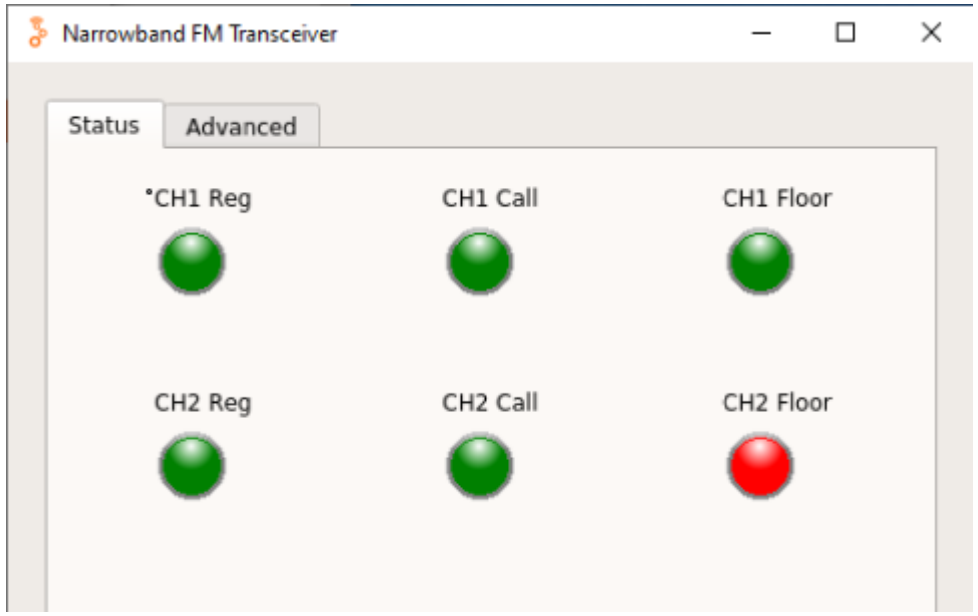
Parameter
Id: squelch
Label: Squelch Level (dB)
Value: -40
Type: Float

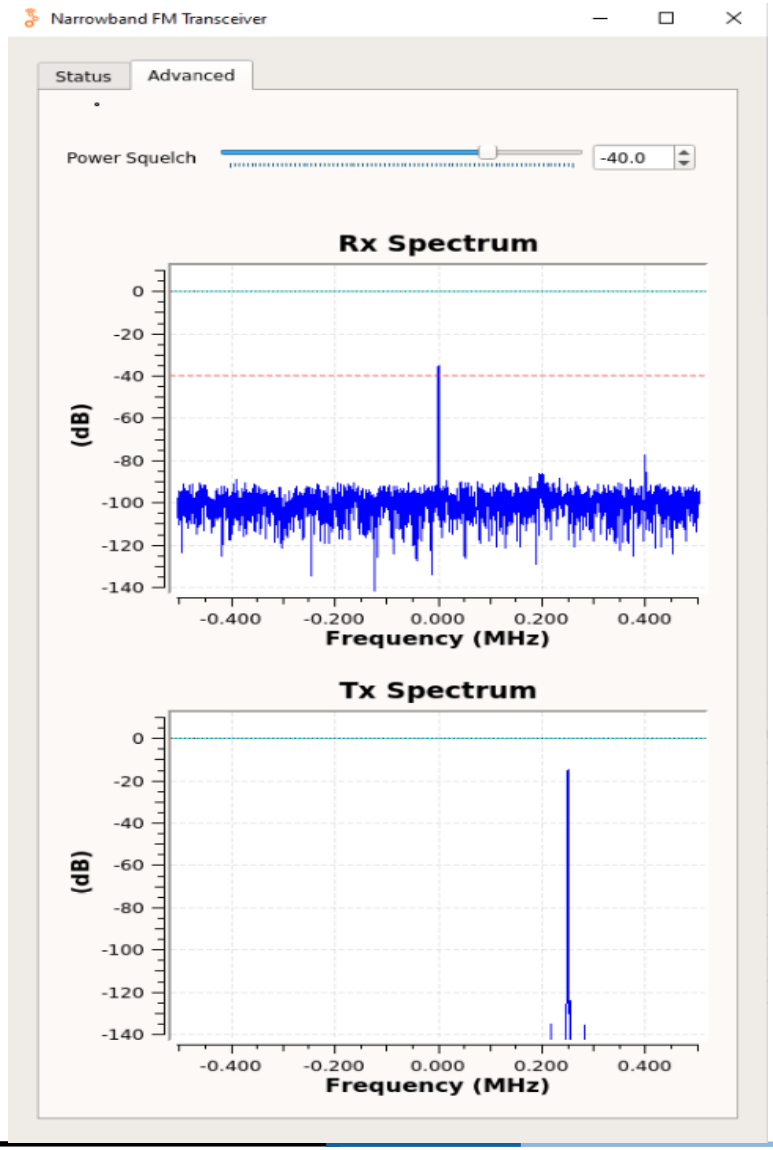
All Receiver and Transmitter Blocks are Hierarchical



TWO CHANNEL OPERATION

- CH1 LMR Receiving Signal
  - GNURadio requests and obtains floor
- CH2 LMR Transmitting Signal
  - MCPTT system has taken the floor





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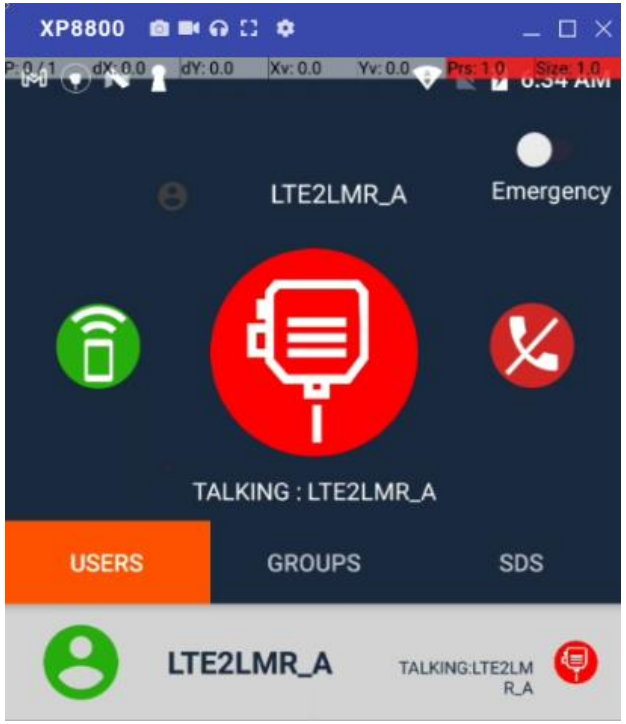
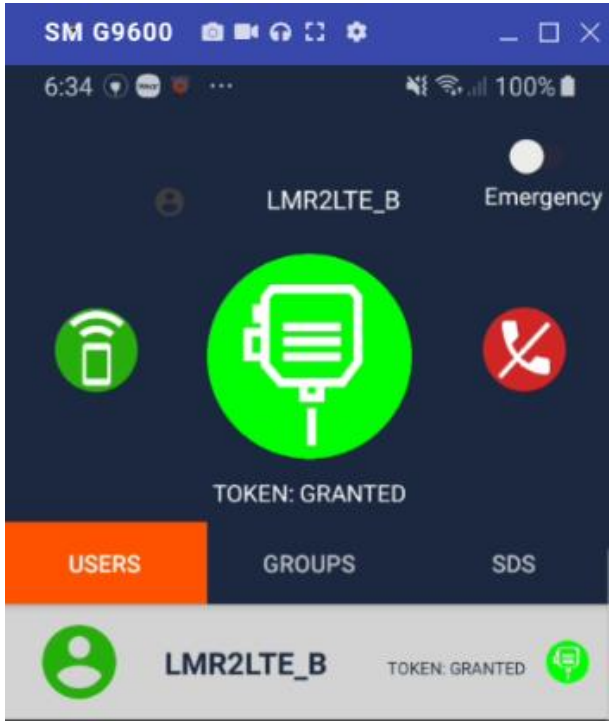


- CH2 LMR Transmitting
  - MCPTT system has taken the floor



CONCLUSION

- SDR and Open-Source Development Solutions
- Challenges
  - Encryption
  - P25 as an established and widely deployed technology
- Prototype Developed
  - Bridge an analog SU into a standards-based MCPTT system
- NISTIR-8338: Bridging Analog Land Mobile Radio to LTE Mission Critical Voice
  - Published Dec-2020

THANK YOU

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