# **Machine Learning Classification of Wireless Communication Signals**

# SenSIP Algorithms and Devices REU

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### ABSTRACT

- Machine learning enhances classification efficiency of wireless transmissions
- Classification reveals transmission techniques for signal decoding
- Applications: Cognitive radios, QoS, and military uses

### **MOTIVATION**

### **Civil Applications**

- Improve data traffic management
- Optimize cognitive radios and quality of service (QoS) of transmissions

### **Military Applications**

- Transmission schemes are generally unknown
- Signal classification necessary for decoding

### MIMO

Increases transmission rates, reduces bit error rate 

### **Artificial Intelligence/Machine Learning**

Using algorithms to automate signal classification

Signal

Machine

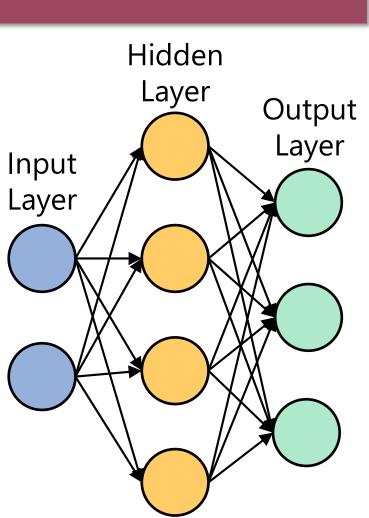
### **PROBLEM STATEMENT**

Detect signals with LimeSDR

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Use convolutional Learning neural networks to classify signals as 2G, 3G, or 4G (LTE)



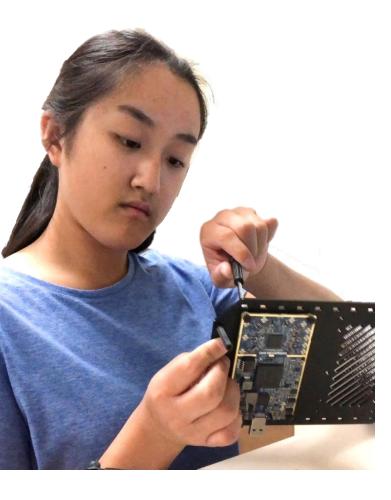


### METHODS

 Manual scanning of 2G, 3G, 4G (LTE) frequency bands Identify signal bandwidths matching standards of Bands 2, 5, 66

### **Antenna Configurations**

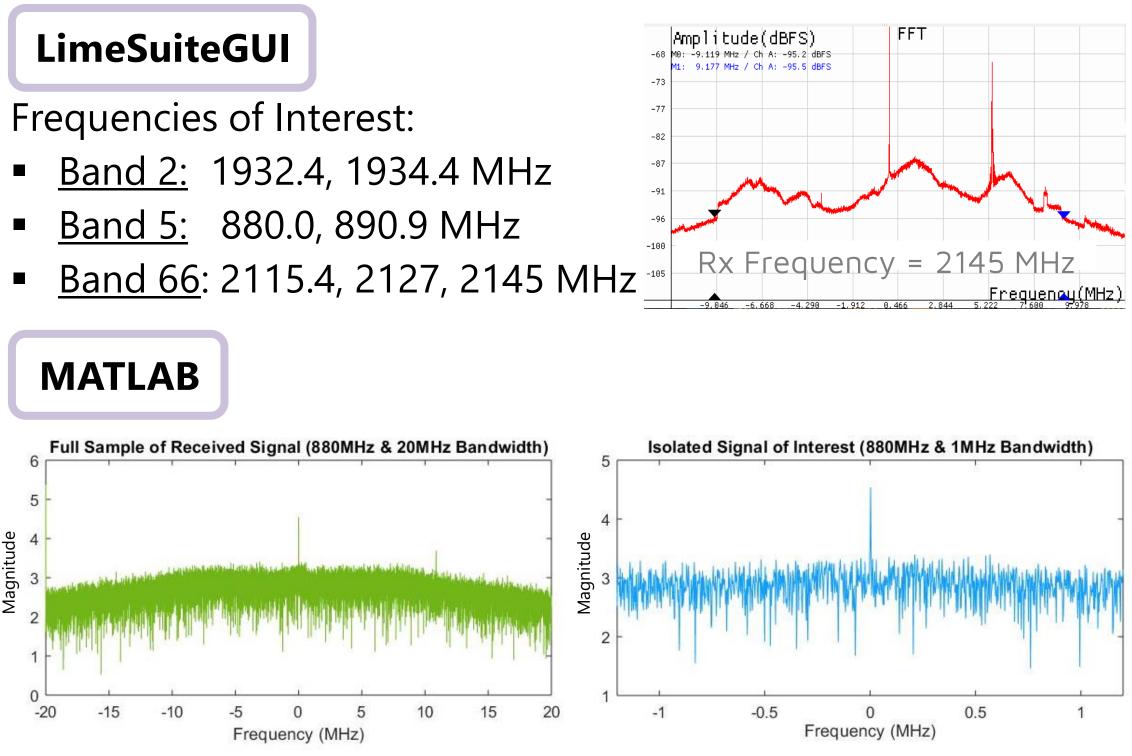
- **Rx**: Wideband (10MHz-2GHz)
- **Tx**: All Frequencies



# Using LimeSuiteGUI interface to operate LimeSDR-USB

| File Options Modules Help   |   |         |   |                  |   |  |      |
|---|---|---------|---|------------------|---|--|------|
| Open Save OA CH   | HANNEL 🔘 B CHANNEL 🗌 Enat                             | le MIMO | Chip->GUI GUI->Chip Reset Default Temper  | ature: 43 C      | Read Temp                                     | FFT Viewer                               |      |
|   | TBB AFE BIAS LDO XBU                                  | F CLKG  | EN SXR SXT LimeLight & PAD TXTSP RXTSP CDS  |                  |   |  |      |
| Power down controls<br>Feedback divider block   | Test mode of SX TST disabled                          | 2000    | IQ samples  | 2000 Q           | iewer<br>I versus Q                           | FFT parameters                           | 90   |
| Charge pump<br>Forward frequency divider  | Trim duty cycle of DIV2 LOCH                          | 1500    |   | 1500             | 1 701 303 4                                   | Nyquist freq (MHz): 20.00000             |      |
| SDM   | Trim duty cycle of DIV4 LOCH                          | 1000    |   | 1000             |   | Samples count 16384                      | -    |
| VCO comparator  | LOCH_DIV division ratio                               | 1000    |   |                  |   | LMS SISO    12 bit format                | -    |
| ✓ Enable SXR/SXT module<br>Direct control ✓ Direct control of PDs and ENs   | Calculated Values for Fractio<br>N Integer: 121       | 500     |   | 500              |   | Loopback RX to TX Sync timesta           |      |
| SXT/SXR controls  | Output Freq, MHz: 1932.400<br>DIV2 prescaler: 0       | 0       |   |                  |   | STOP Rx rate: 40.985 M<br>Tx rate: 0 B/s | MB/s |
| Reset SX Bypass noise filter resistor   | CSW_VCO   | -500    |   | -500             |   | Window function:<br>Rectangular          |      |
| Bypass SX LDO   | Scales VCO bias current                               | -1000   |   | 1000             |   | Capture to file                          |      |
| Enable coarse tuning<br>Enable current limit  |   |         |   | 1500             |   | Capture enable                           |      |
| Reverse pulses of PFD<br>Enable INTEGER N mode  | Scales pulse current of charge p<br>Reference voltage |         | 100 200 300 400 500 600 700 800 900 1000  | 2000 -2000 -1000 | 0 0 1000 200                                  | Samples to capture: 16384 ‡              |      |
| Enable SDM clock  | PLL LPF zero resistor: Rzero =                        | l lı    | Amplitude(dBFS)   | FT               |   | Freeze time                              |      |
| Reverse SDM clock<br>Enable dithering in SDM  | CMPLO_CTRL: Low three                                 | -12     |   |                  |   | Freeze constellation                     |      |
| ((  |   | -23     |   |                  |   | Display channel:                         |      |
| 11:28:23] INFO: Reference clock 30.72 MHz<br>11:28:23] INFO: Connected Control port: LimeSDR-USB FW:4 HW:<br>11:28:55] INFO: SXR frequency set to 1932.400000 MHz<br>11:28:57] INFO: SXR frequency set to 1932.400000 MHz<br>11:29:00] INFO: SXT frequency set to 2400.000000 MHz<br>11:29:02] INFO: CGEN frequency set to 319.999999 MHz |   | -34     |   |                  |   | FFT averaging: 50 ‡                      |      |
|   |   | -46     |   |                  |   | Buffers status                           |      |
|   |   | -58     |   |                  |   | Rx:                                      |      |
| 11:29:11] INFO: RX LPF configured   |   | -69     |   |                  |   | Tx:                                      |      |
| Control   | port: LimeSDR-USB FW:4 HW:4 I                         | -80     |   |                  |   | Measurement Ch 1 Ch 2                    | 2    |
|   |   | -92     | the second |                  |   | Center offset (MHz):                     |      |
|   |   | -104    |   |                  | Frequency(MHz)                                |  |      |
|   |   |         | -16.000 -12.000 -8.000 -4.000 0.000   | 4.000 8.0        | <u>11 CUUCIICUUIIIZ,</u><br>100 12.000 16.000 | Power (dBES). 222 222                    |      |

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### Next Steps:

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# Sen

INDUSTRY CONSORTIUM

## PRELIMINARY RESULTS

Signal recreated in MATLAB with LimeSuiteGUI I/Q samples Determined specific channels to isolate signals

### **CONCLUDING REMARKS**

### What I Learned:

SDRs use software to implement hardware components

Switch to signal transmissions simulated by USRPs Analyze signal samples for features; train machine learning

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