



# Wireless Signal Processing Education



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# Outline

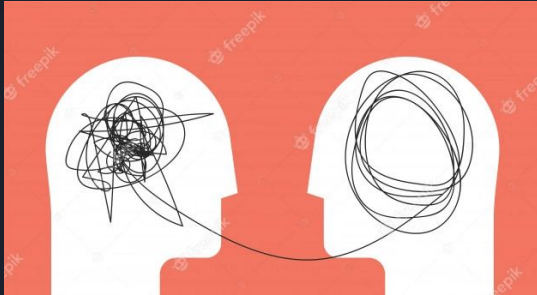
Motivation

Curriculum

Standalone Educational Kit - HaKi

Next Steps

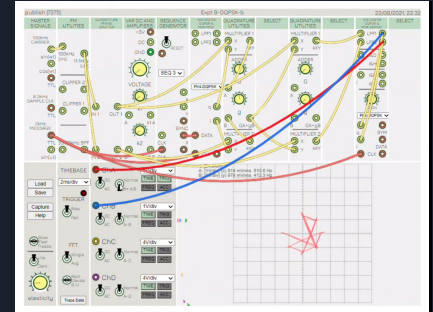
# Problems



Complex & Abstract



Proprietary & Expensive



Simulation-only



Hardware-based



Time&Place Restricted



Lacking Software

# Solution



Open System



Modular



Real-world Signals



Professional  
Development



Mobility/Remote



Software-based

# TOBB ELE361L Course



RF Front-End (RFFE)



Student Laptop



# Curriculum

Labs based on Jupyter Notebook

- DSP
- SDR
- Python/Matlab
- AM
- NBFM
- WBFM
- Digital
- ADSB

The image is a collage of logos and a screenshot. At the top center is the GNU Radio logo, which consists of three orange circles of varying sizes arranged in a triangular pattern, followed by the text "GNU Radio" in orange and "THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM" in smaller black text below it. To the left of the Python logo is the MATLAB logo, featuring a blue square with a 3D orange and red surface plot and the word "MATLAB" in white. To the right of the MATLAB logo is the Python logo, which is a blue and yellow snake-like figure with the word "python" in blue below it. Below these logos is the Jupyter logo, which is an orange circle with a white crescent shape inside, and the word "jupyter" in white. To the right of the Jupyter logo is a green chalkboard on a black stand, with a white GitHub logo on it. At the bottom of the collage is a screenshot of a software-defined radio (SDR) interface. The interface shows a spectrum analyzer at the top with a white signal trace on a black background. Below the spectrum analyzer is a waterfall plot with a blue background and white and yellow signal traces. The interface has a dark theme and various control buttons and sliders.

# Goals

- Engagement
  - Interesting real-world projects
  - Building DSP/Programming/Technical skills
- Unique
  - Windows/Linux/Mac
  - All-in-one: Apps+GNU Radio+JupyterLab
  - Matlab/Python
  - Remote-ready



# Learning Outcomes: Weeks 1-5

DSP/Comm.

Tech. (Tools/Libs/Programming)

Week-1	Introduction to Communication Systems, SDR Fundamentals
	GitHub, GitHub Classroom, Markdown
Week-2	DSP Fundamentals
	Conda, GNU Radio
Week-3	Sound card processing, Basic filtering (filter type: HP/LP/BP, cutoff frequencies, taps, transition bandwidth ...), Nyquist Theorem, Aliasing
	Git, GNU Radio Companion, GNU Radio flowgraph creation
Week-4	Sound card processing, Multirate SP, Decimation, Stereo sound and DTMF tone generation
	Git, GNU Radio
Week-5	FFT, Frequency resolution, Negative frequencies, Nyquist, Ideal LowPass filter
	Jupyter-lab, Matlab/Python



# Learning Outcomes: Weeks 6-10

DSP/Comm.

Tech. (Tools/Libs/Programming)

Week-6	AM, HF Band, Airband, IQ record types (RTL-SDR, USRP)
	Osmocom Software Suite (rtl_test, rtl_sdr), SDR#, Matlab/Python
Week-7	NBFM, VHF band, Handheld Radios, FM Repeaters, CTCSS
	Osmocom Software Suite (rtl_sdr), SDR#, Matlab/Python
Week-8	Wide Band FM Components: Mono/Stereo, Pilot tones, RDS, Subchannels
	Osmocom Software Suite (rtl_sdr), SDR#, Matlab/Python
Week-9	Digital Signals, QPSK, Constellation, Pulse shaping, Synchronization, Decoding
	GNU Radio
Week-10	Digital Comm. Signal (ASD-B), Preamble, Manchester encoding, Thresholding
	Osmocom Software Suite (rtl_sdr, rtl_adsb), SDRAngel, Matlab/Python

# Summer 2021, Fall 2022

All students agree that

- “Course engaged me in learning Communication Systems”
- “I learned new tools I can use in future”

GitHub Classroom is liked by 100%

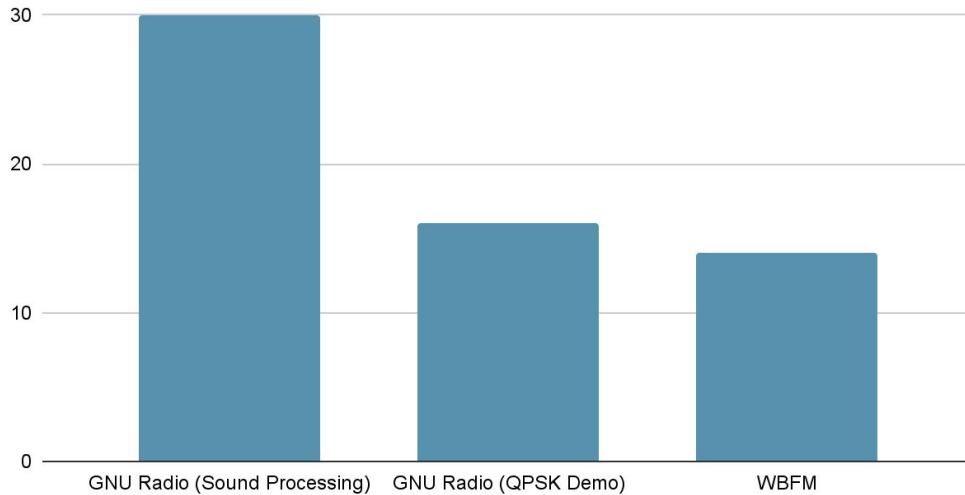
Python is preferred over Matlab



# The winner: GNU Radio



Number of Votes



# Communication Kit Project

- Low-cost
- FOSS
- Ready-to-go, one-place platform
- Programming skills
- Suitable to IoT, DL, DIY projects



# Wireless Signal Processing at the Edge



RF Front-End (RFFE)



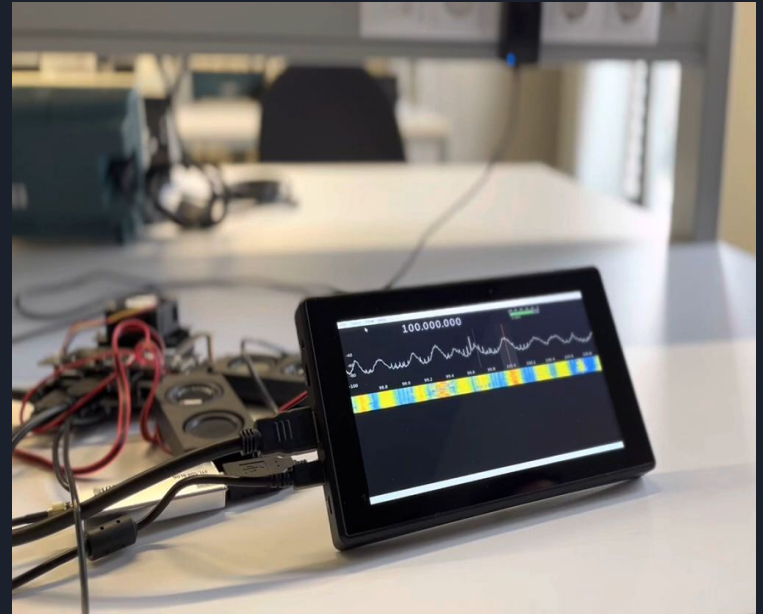
7-inch Capacitive Touch Display  
(Optional)



Single Board Computer (SBC)



# HaKi GUI



# Grants



NVIDIA Academic Hardware Grant



ARDC Education Grant



# Next Steps

More modules

Advanced content (graduate study)

Step-up SDRs

GPU acceleration (CUDA/cuSignal)

Useful Deep Learning applications



# Thanks



Teach your students

- to doubt,
- to think,
- to communicate,
- to question,
- to make mistakes,
- to learn from their mistakes,  
and most importantly
- *have fun in their learning*