Field Radio

The University of Central Florida
Department of Electrical Engineering and Computer Science

Dr. Lei Wei Senior Design I: Spring 2022

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Sponsored by and in association with Amateur Radio Club @ UCF

Table of Contents

Field Radio **1**

Table of Contents **2**

Project: Handheld SDR Radio based on LIME **4**
- Customers and Sponsors 4
- Description 4
- Motivation 4
- Goals/Objectives 4
- Functionality 4
- Risks 5

Requirements and Deliverables: **6**
- RF requirements 6
- Portability 7
- Programmability 7
- Spurious Emissions/EMI 7
- Easy to Use 7
- Configurable and multipurpose 7

Constraints **8**
- Related Standards 8

Prototyping: **9**
- Research related to project 9
  - Existing technology 9
  - Possible components 9
    - SDR Receiver 9
    - Embedded System 9
    - Antenna 10
    - Battery/Battery Charger 10
    - Touchscreen 10
- Software Block Diagram 11
- Hardware Block Diagram 12

Budget: **12**
- Bill of Materials 12

Timeline and Milestones: **14**
- ABET timeline 14
- Radio club timeline 15

Project: Handheld SDR Radio based on LIME

Customers and Sponsors

UCF (Customer): Senior design project to be delivered to demonstrate competence in engineering for degree completion
Amateur Radio Club (Customer/Sponsor): Provides funding and resources for the project in exchange for the deliverable and source code to be given to them at the end of the semester
Amateur Ham Radio Community (Customer): Will have access to the source code and design to be able to recreate or purchase their own version of what we will be working on

Description

This project will be a user-friendly handheld software-defined radio. Per our initial research, the LimeSDR mini and LimeSDR are both good candidates to serve as the base for our project, and we will be using additional hardware to add various features and make it more user-friendly.

Motivation

The reason that we are working on this project is that there is currently no open-source design for a user-friendly SDR available to the HAM radio community. This is problematic because a lot of the handheld radios available in the market have closed-source designs, and are often made with shoddy materials.

Goals/Objectives

We aim to fix the aforementioned lack of an open-source handheld SDR by using the LIME to develop a baseline that future hobbyists, developers, and students can build off of to add additional features to. This was at the request of the Amateur Radio Club, our Sponsor. The main goal of the project is to meet all of the functional requirements while still allowing for expandability so that the optional requirements could be introduced at a later point.

Functionality

The following features are required for the final product and therefore it will have each of these functionalities:

- Receive and transmit FM signals
- Receive AM signals

- Low cost
- Adjustable power level
- Single antenna
- Display
- External Controls
- Long battery life
- Open Source Software Design
- Fully Programmable from a computer
- Modular
- Memory presets for FM use
- Interfaces with field program FM frequencies from 100 to 1000
- Configurable
- Multipurpose
- Easy to use
- Portable

The following features are optional, but the design of the base product should support these being added as either software expansions or hardware plugins:

- Touchscreen
- Automatic signal recognition
- Store either demodulated voice or I/Q samples to a microSD card
- Expanded UI through phones via bluetooth or USB
- Waterproofing against rain
- Battery level Indicator
- Satellite communication features
- Waterfall display via spectrum scope
- GPS support including: APRS, time sync (should be in the form of a hardware plugin)
- Expanded transmission support for 900Mhz at 1W-5W
- Additional encoding and decoding modes, including AM FM DFM APRS DSTAR Fusion DMR DRM codec2 SSB
- Receive NOAA weather radio signals and support for alerting with SAME

Risks

There are various risks that we will have to deal with that are either general risks for any senior design project, or risks specific to this project. We have attempted to come up with ways to mitigate these risks as much as possible.

Due to both the size of the group and the length of time that this project will be worked on, it is perfectly reasonable to assume that there will come a point where a group member may face unforeseen circumstances and be unable to complete their portion of work for a given period. Fortunately, our group consists of an even split of two Electrical Engineering majors and two Computer Engineering majors. Therefore, as long as we all do our due diligence when it comes to documenting what we are working on, there will always be somebody else on the team available with enough overlap in knowledge to complete a team member's part.

With the global chip shortage, many electronic parts are in high demand right now and are difficult to obtain. To help prevent this from affecting the timeline of our project completion, the Amateur Radio Club @ UCF has already ordered some of the expensive or hard to obtain parts that we would need to complete the project, including a LimeSDR.

A frequent issue that we have seen cited by our predecessors in Senior Design have been that their project was difficult to complete due to miscommunication or lack of communication between the group members and the stakeholders, such as the sponsor or potential customers. In our case, the Amateur Radio Club serves as both a sponsor and a customer, so as long as we keep the channels of communication with them open there should be no issues. Additionally, one of our group members is in the Amateur Radio Club, so they will have constant contact and opportunities for communication with our primary stakeholder. Finally, one of our group members has spoken directly to chip manufacturers and they mentioned that they would be willing to work with students to make sure we have the chips.

Requirements and Deliverables:

Because this is a sponsored project The Amatuer Radio Club at UCF has consulted and had input on several requirements for the deliverables:

RF requirements

- Support out of the box for FM RX/TX, and AM RX for configured amplifiers
- Able to transmit and receive on multiple bands on a single antenna
- Support repeater interaction features: CTCSS standard subaudible tones (88-200hz) and tone squelch (RX/TX); duplex operation (TX/RX offset, offset polarity (+ 0 -)), touchtone generation

Portability

- Have a transmitting power output of 3-5 watts for a minimum of 25 minutes
- Able to remain on standby demodulating FM signals for a minimum of 5 hours
- Easily sunlight readable screen
- Charge through USB at 5 volts
- Have multiple field configurable and modular amplifiers at one time for different frequency bands

Programmability

- Entirely open source and free for adaptation by the radio community
- Completely and easily programmable including reusable SDK and documentation on all code
- Able to connect to a computer and be reprogrammed over USB or WIFI in the field

Spurious Emissions/EMI

- Filter stairstep radio synthesizer output to prevent spurious emissions
- meet emi, modulation, Drift, and frequency accuracy as defined by the FCC
- Discussed further in related standards under constraints

Easy to Use

- GUI for controller and setup of radio in the field
- GUI documentation allowing for easy adoption
- Connectors, fasteners, and components that do not require uncommon tools: E.G. should use common components no apple style design
- Documentation on common hardware use case for repair

Configurable and multipurpose

- Matches community standards and expectation for cost and complexity allowing for widespread community adoption
- Amplifiers should be modular and fairly interchangeable without compromising noise characteristics
- Uses well documented open source libraries
- Supports common connector types

Constraints

The following constraints were determined by the team to be the most significant logistical challenges to the projects success:

- One of the main constraints determined by our team is time: Everyone in this team works at least 20 hours a week, so efficient usage of time is a mandatory constraint for success of the project
- The second most important constraint is component availability. The components must be widely available and mostly unaffected by the current semiconductor shortage. For this reason popular parts should be used
- Although funded by radio club total cost of components should not exceed 500 dollars

Related Standards

Must comply with transmitting noise and power standard set by FCC CFR Title 47:part 97
Including but not limited to:

- Angle modulation must have a modulation index less than 1.
- No non phone emissions shall exceed the bandwidth on phone quality emissions using the same modulation scheme
- The total bandwidth of side band emissions shall not exceed A3E emission quality which is full quality dsb amplitude modulation of voice in low frequencies with spurious side band amplitude at a maximum of what is defined in FCC CFR title 47 part 95.635 unwanted radiation
- The baud rate of radio teletype emissions must not exceed that which is defined in part 97 for each band
- The meaning or intention of any transmission not use for direct control of a satellite as defined in part 97 must not be obscured
- All components must meet EMI standard defined in fcc part 97
- The last constraint we considered is the requirement of amateur licenses by the FCC to transmit on amateur bands one of the group mates already has a license but because of this transmission testing must be done with a liscensed amatuer present. So other teammates may need to get a license

Prototyping:

Research related to project

Existing technology

Software Defined Radio (SDR) is a way for people to listen to a wide range of radio frequencies and channels such as local radio, emergency stations, air traffic control, and even signals from the International Space Station via an SDR receiver and a software program that demodulates, filters and enhances the sound. SDR receivers have become widely accessible and affordable in recent years with hobbyist models such as the NooElec NESDR Mini 2 costing as little as $25. Higher end SDR receivers such as the LimeSDR, HackRF One, and portable SDR receivers cost $299. There are also many windows and multiplatform SDR software programs such as the sdr Console V3, SDR Sharp #, and SDRplay SDRuno that work with the SDR receivers that allow you to cycle through the radio frequencies and perform additional functions.

Possible components

SDR Receiver

The preferred SDR receiver we will use to design the project will be the LimeSDR Mini. The LimeSDR Mini features the same radio transceiver as the full sized LimeSDR model at a fraction of the size, cost, and weight. The main differences between the two boards are that the LimeSDR Mini is a two channel device instead of a four channel, as well as having common SMA antenna connectors rather than micro U.FL antenna connectors.

Embedded System

The chosen embedded system we will design the SDR Radio around will be the Raspberry Pi. The Raspberry Pi is a small and powerful single board computer that uses the Linux operating system and is an embedded system which fulfills many of the required and optional features of the portable radio. Via the Raspberry Pi's onboard GPIO modules can be plugged directly into the GPIO in the form of a Pi Hat such as a touchscreen, battery holder/charge controller, or GPS module. Onboard USB ports and a 3.5mm audio port allow for the SDR receiver to be connected as well as a speaker and microphone.

Antenna

Since the two most preferred options by the radio club are the LimeSDR Mini and the Cariboulite Raspberry Pi hat, the antenna we will be using for the radio will have a coaxial RF SMA connector that can be plugged into both boards.

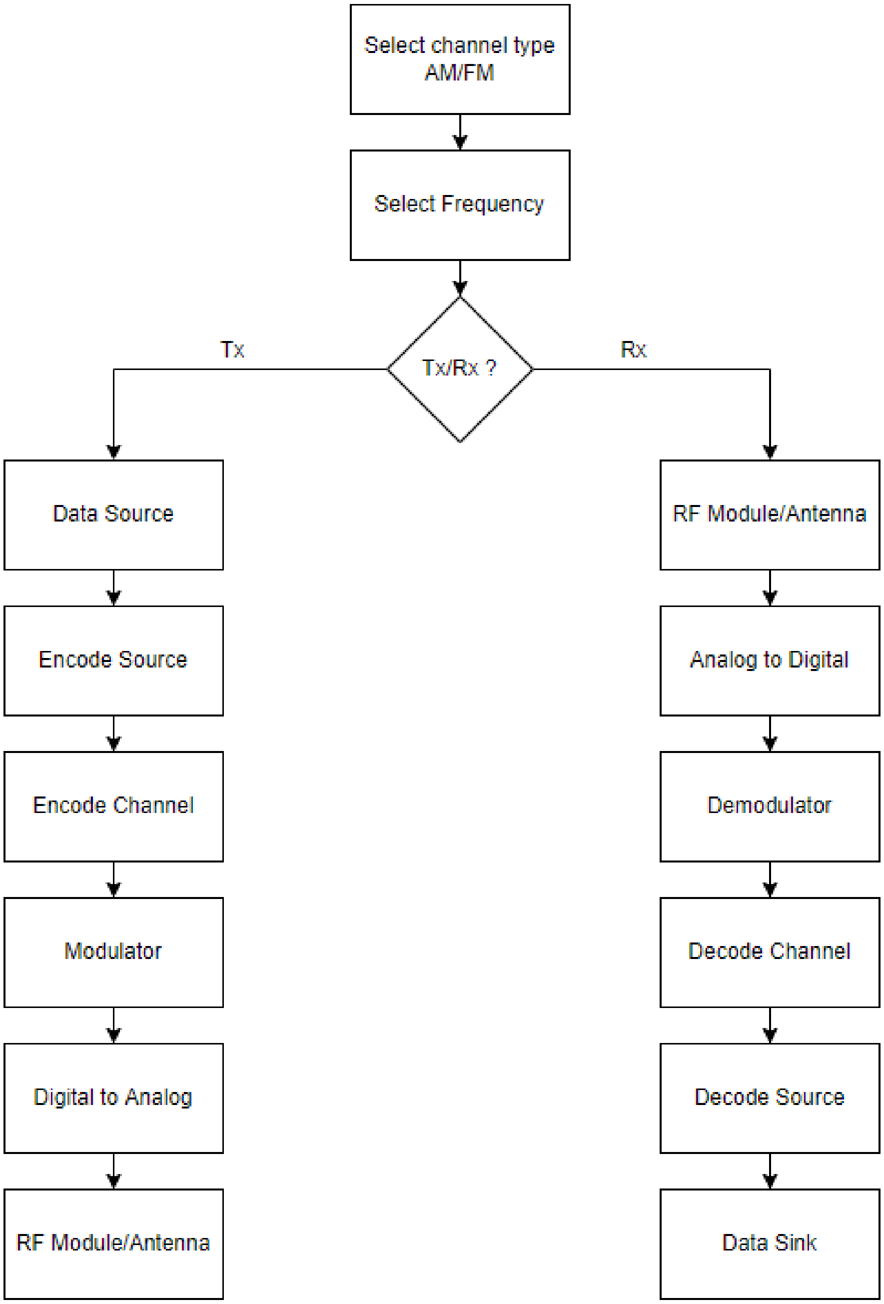
Battery/Battery Charger

The preferred battery lifetime for the device is five hours and the battery would have to power the Raspberry Pi, the LimeSDR Mini, and any peripherals that are added to the system. For the system, the most versatile battery type we could use would be the lithium ion battery. Coming in many form factors such as a complete portable power station solution or a combination of lithium batteries and a battery charging module. The battery charging module would charge the batteries using a 5V input source as well as provide information on the voltage level of the batteries which we could then use to calculate the battery life percentage.

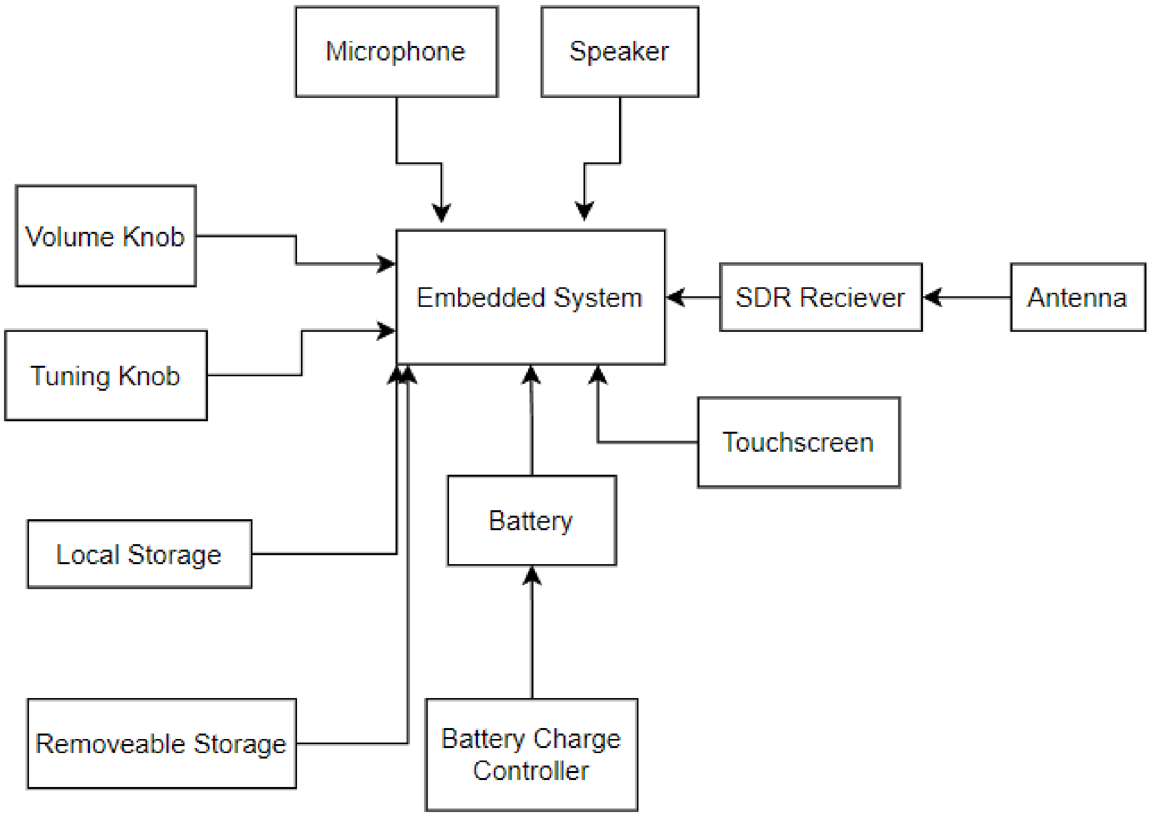
Touchscreen

In order to control the SDR, a touch screen will be used to access all the functions of the program. Ideally the touch screen would be water-proof or at the least water-resistant since the device would primarily be used outdoors. Due to this we should favor a resistive touch screen over a capacitive touch screen since we would likely not use the multi touch capability of a capacitive touch screen and resistive touch screens have a double screen separated by air.

Software Block Diagram



Hardware Block Diagram



Budget:

Bill of Materials

The Club Faculty Advisor of ARC@UCF and CECS computer cluster researcher will be sponsoring this project on behalf of ARC@UCF as well as providing access to their laboratory and tools they have available. A target goal for this project is for the radio to cost $300-500 to build, keeping in mind that a prototype may cost more in the designing process (this budget in mind also excludes additional accessories such as GPS that can be implemented as a hardware extension). This budget is a target as this handheld SDR should be readily accessible to customers looking to operate in the amateur bands of radio. Researching, we found that radios that generally perform similar functions to our SDR radio are significantly more expensive, often in the $5000 range. Our sponsor has not specified a value as to our upper limit of budgeting, but insists to keep the cost as close to $500 as possible.

Estimated Cost Table

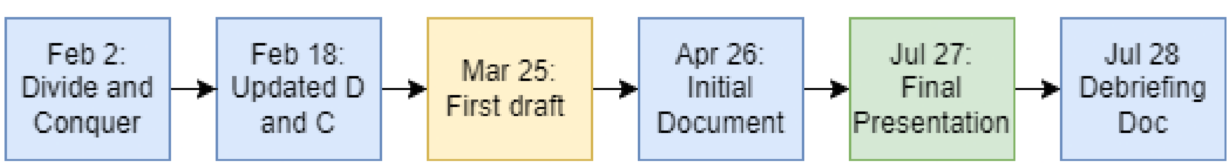
Component	Description	Quantity	Vendor(s)	Estimated Cost
LimeSDR Mini	Software defined radio component, primary core of SDR radio	1	Limemicro LLC	$199
Raspberry Pi Zero 2 W	Embedded Control CPU	1	iUniker (Amazon)	$10
TX Amplifier (Currently Undecided)	Radio Frequency Amplifier	1	Specific amplifier undecided	$20
Antenna port	BNC supportive Antenna capable of accepting external antenna	1	Specific antenna undecided	$10
Touchscreen Display	Resistive based water resistant HUD for user to interact	1	Specific touch sensor and controller undecided	$30
Speaker	Multipurpose speaker(s) for signal production	1	Specific part undecided	$10
Microphone	Multipurpose microphone(s) for signal capture and recognition	1	Specific microphone condenser not selected	$10
PTT Switch	Push-To-Talk switch facilitating conversations across various communication	1	Specific part not selected	<$1

	lines			
Battery/Battery Controller	Battery and casing system capable of supporting power to system	1	Specific component not selected	$30
Waterproof Casing	Protection of radio system and casing, 3D printed	1	-	$20
Gasket	Sealant for waterproof casing in case PLA is used	1	-	$12
Miscellaneous	Electronic components (Resistors, Capacitors, etc)	-	Mouser, Digikey, Etc	~$10
Total Estimated Cost	$362			

Timeline and Milestones:

The overall time should roughly follow these diagrams leaving a large amount of time for integration and unpredictable challenges:

ABET timeline



Radio club timeline