In-Band Communications in DC Microgrids

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Original: Austin Burnham, Michael Lee, William Phang, Timothy Tran
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Problem

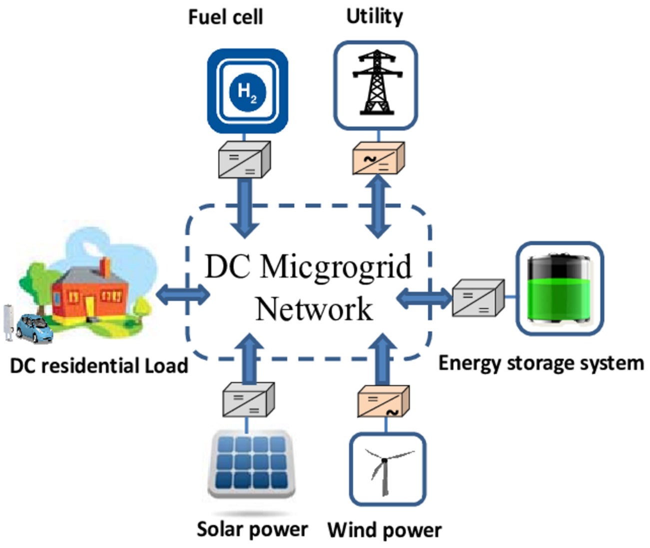
- UN in 2020: At least 786 million people still do not have access to electricity.

- Developing areas may not have the adequate resources to distribute power central power or house a generator.

- Natural disasters – e.g. California wildfires right now.

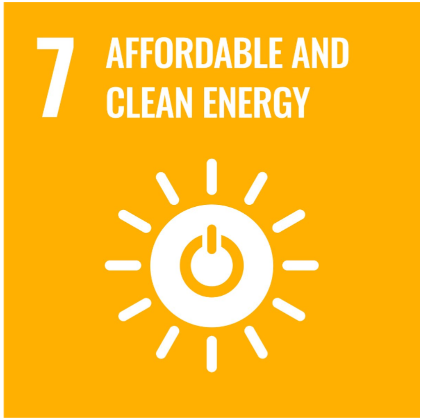
DC Microgrid

- Contain a DC power source, storage, and loads.
- Can be operated with little to no experience with electrical power.
- Implement the functionality of multiple downstream devices to facilitate multiple units.



Motivation

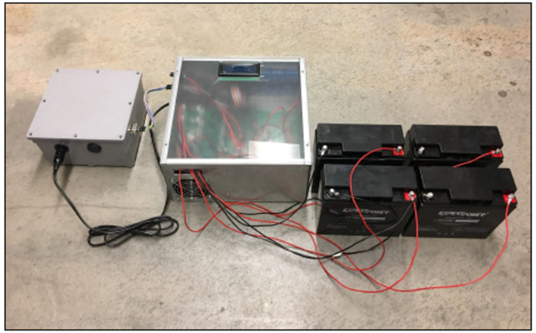
- Assist in disaster relief efforts.
- Facilitate clean, renewable energy.
- Gives regions and areas around the world access to electricity.



Past Work (advised by Joseph Decuir)

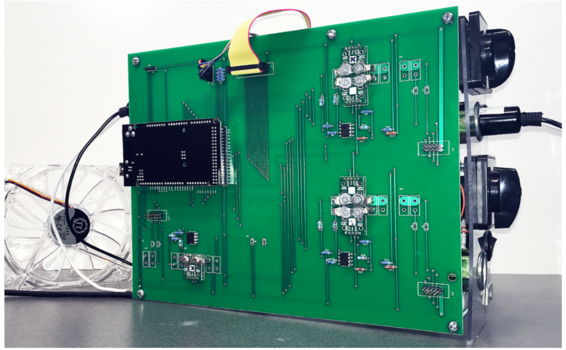
2030.10 Base Team - Spring 2018

Htut Ko, Alan Nguyen, Phuoc Thai, Hau Tran



2030.10 Extension Team - Summer 2018

Karinne Barbosa, Sarah Dunning, Gareth Ho, Andrew Nguyen, Addison Redfield



Our Team's Objectives

- Prove that power and communication on the same cable is feasible.
- Investigate the RFM69CW transceiver and its functionalities.
- See how reliable the communication is on the line, at certain baud rates.
- Reduce radiation and power loss from the line.
- *Problem: this was a remote quarter; no access to physical labs*

Specifications

- Develop an in-band communications system, while having power on the same line.
- Implement the RFM69CW transceiver into our design.
- Be able to deliver the four voltage ranges of 12V, 24V , 36V , and 48V at up to 10A.
- Practical problem: since all remote, the testing was done a current but at lower voltages.

System Implementation

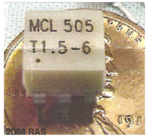
Overview

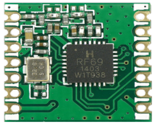
Hardware

- RFM69CW transceiver
- Arduino microcontrollers
- Unshielded, 30m cable copper
- Power Supply
- EMI/RFI Filters
- Coupling Transformer

Software

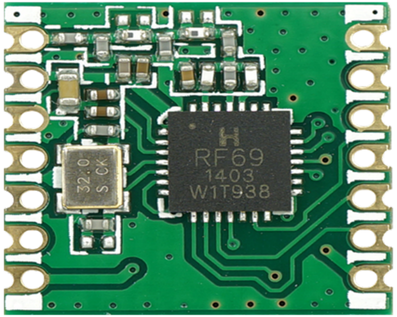
- LowPowerLab's RFM69 Arduino library
- Simulations (LTspice, Multisim)
- Schematic design (EasyEDA, EAGLE)





System Implementation

RFM69CW



- Programmable -18dBm to +13dBm output capability
- High sensitivity down to -120dBm @ 1.2kbps
- Power-saving capabilities
- 115dB+ Dynamic Range Received Signal Strength Indicator (RSSI)
- Operating at license-free carrier frequencies: 315MHz, 433MHz, 868MHz, 915MHz

- Note: this chip, and this module, are commonly used in key fobs and other wireless access
- The chip uses assorted unlicensed radio spectrum
- The chip includes optional AES encryption/decription

Theory of Operation

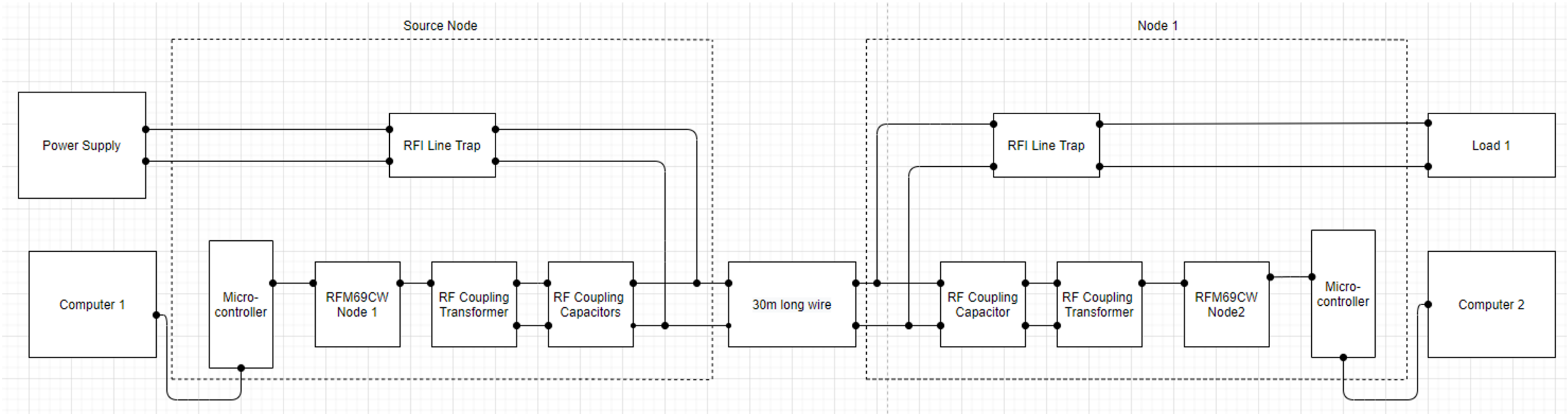
- RFM69CW
  - Transceiver is connected to Arduino microcontroller operated via Serial Bus
  - Microcontroller is connected to a computer which can access the microcontroller via serial monitor

- Communication Coupling
  - Transformer - Single to Differential
  - Capacitors - Allows AC signals through, but blocks DC

- EMI Filters
  - Inductors - Allow DC signals through, but block AC signals

Design

Block Diagram

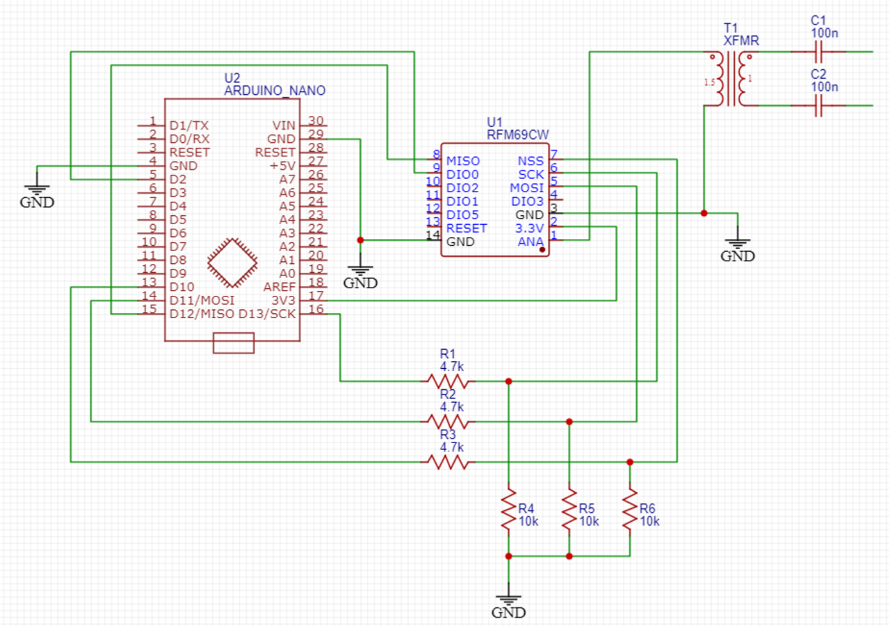


Design

Node with Differential Coupling

Level shifting

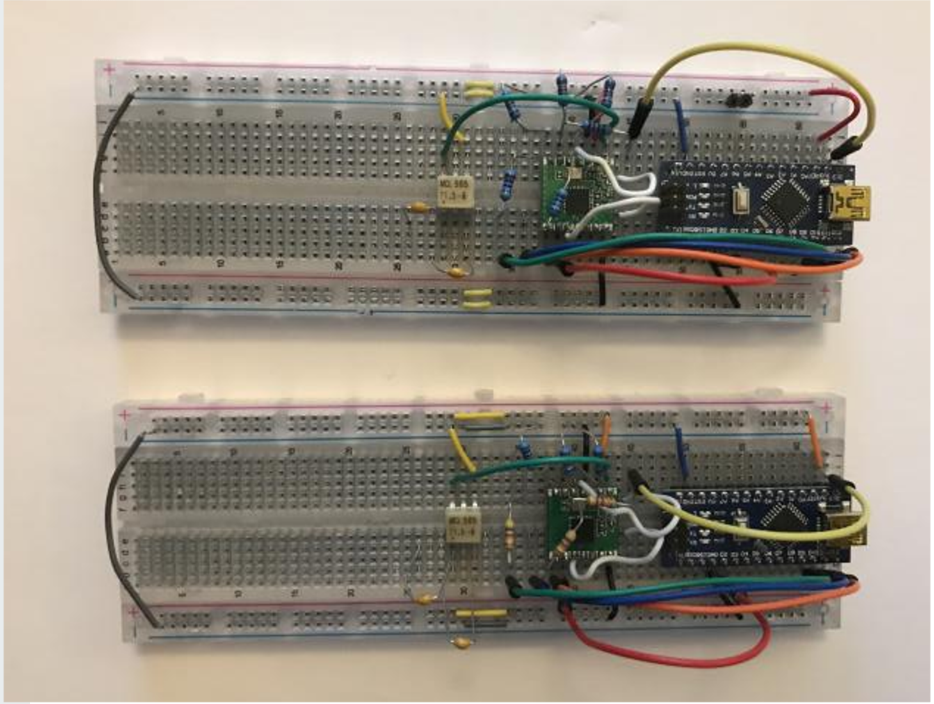
- Arduino microcontroller has 5V I/O pin but 3.3V desired for RFM69CW module.
- Can be achieved using 4.7KΩ and 10KΩ resistors and make a voltage divider.
- 5V * (10K / (10K+4.7K)) = 3.4V



Design

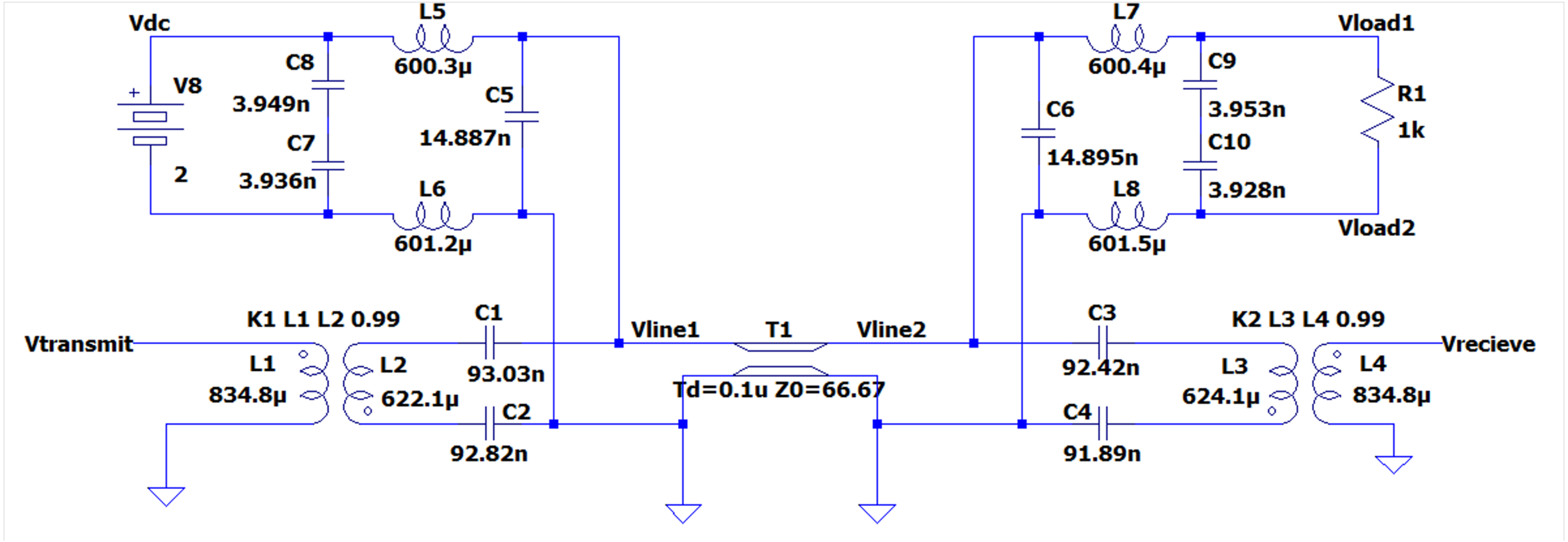
Team Implementation of a Node

Note: since the quarter was all remote we did not have access to PCB layout



Design

In-Band System, Diagram



Design

In-Band System - Main Simulations

Figure 1: Simulated Vtransmit and Vreceive

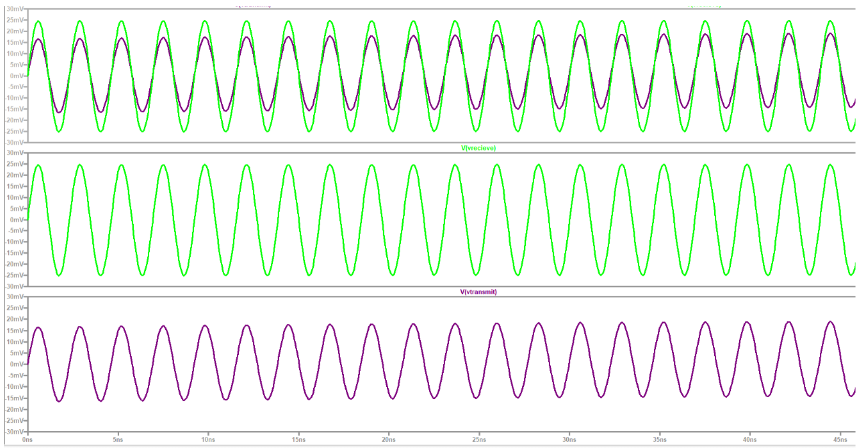
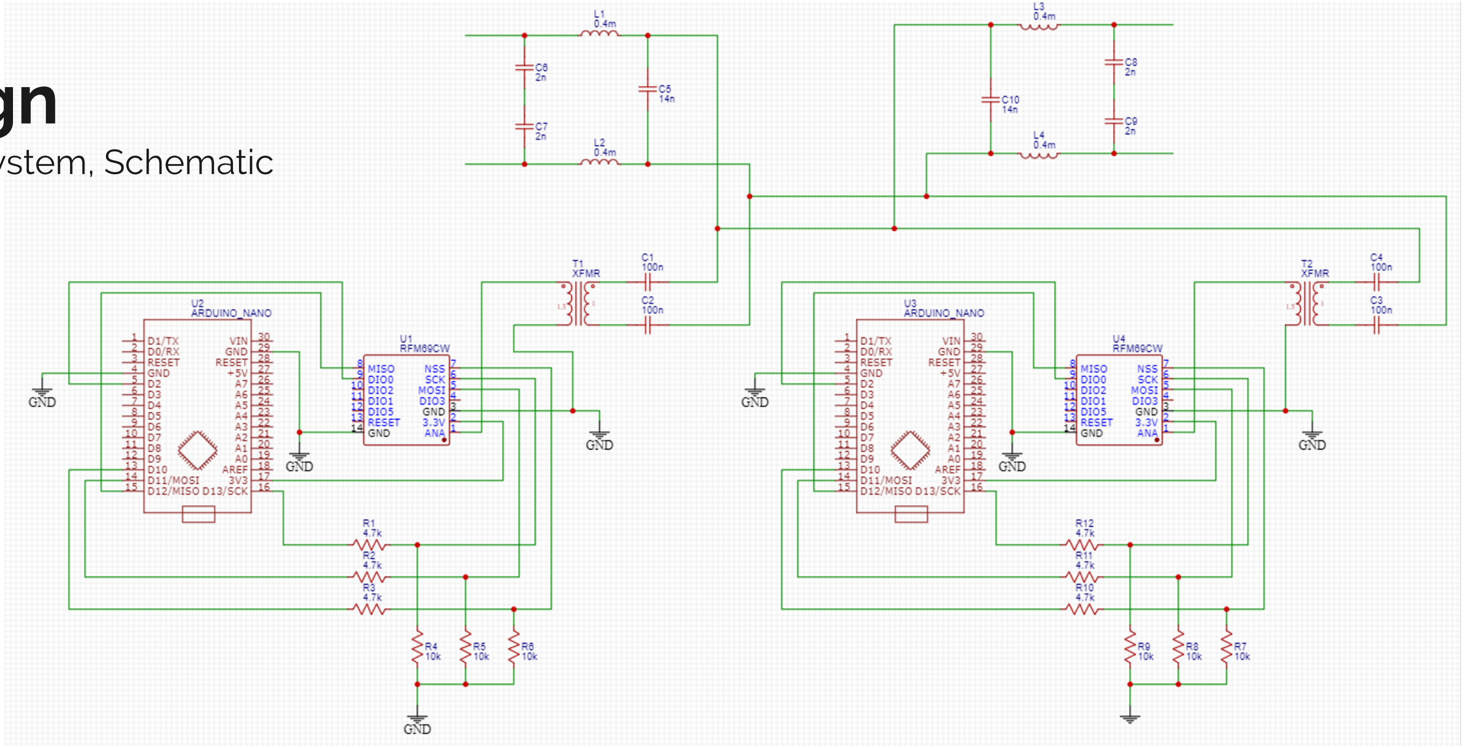


Figure 2: Vsource and Vload Differential

Design

In-Band System, Schematic



Testing

Objectives

- Test communication of the RFM69CW transceivers at 315MHz and 433MHz
- Collecting RSSI values from the serial monitors on the computers
- Verifying the RSSI Values from a SDR (Software Defined Radio) USB Dongle
    - We did not have lab access, and the lab oscilloscopes are limited to 100 MHz
- Deliver voltage to charge a load while communicating between one node to the other
- Reliability of the signal being sent from one node to another

Testing

Results

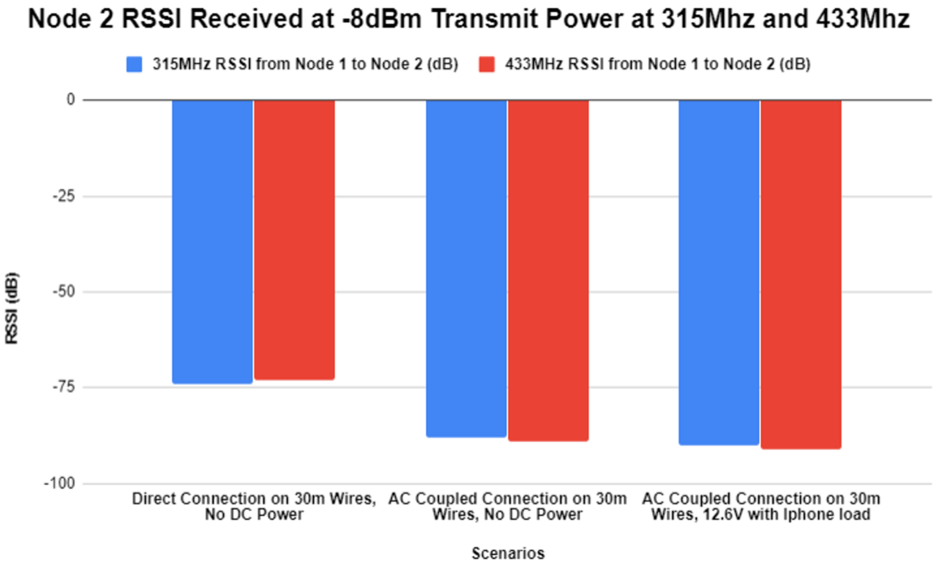
- Communication between the two nodes were successfully established
  - Had to increase transmit power from -18dBm to -8dBm
  - -90dBm RSSI for reliable communication
- Code modified from LowPowerLab interacts well with the RFM69CW
- Small difference between the 315Mhz and 433Mhz, Not frequency sensitive

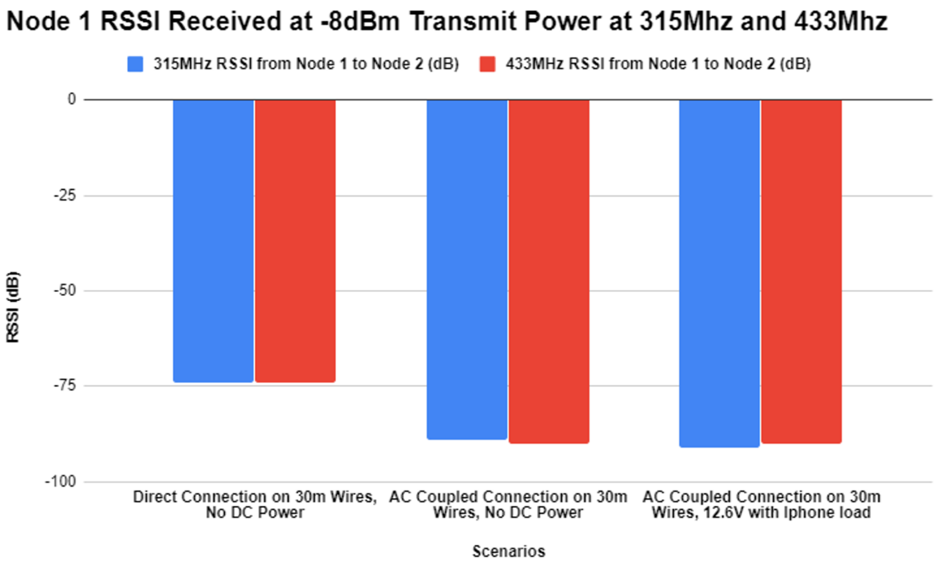
Results at -18dBm Transmit Power

315Mhz & 433MHz Scenarios	RSSI from Node 1 to Node 2 (dB)	Send Time from Node 1 to Node 2 (ms)	RSSI from Node 2 to Node 1 (dB)	Send Time from Node 2 to Node 1 (ms)
Direct Connection on Short Wires, No DC Power	-43	Less than 1	-41	Less than 1
Direct Connection on 30m Wires, No DC Power	No Response	No Response	No Response	No Response

Testing

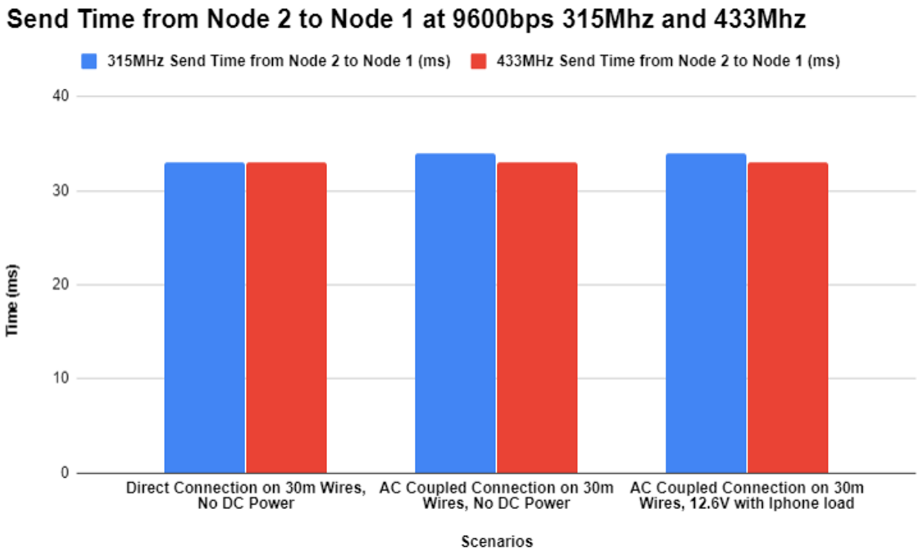
Results - RSSI at the Receiving Node

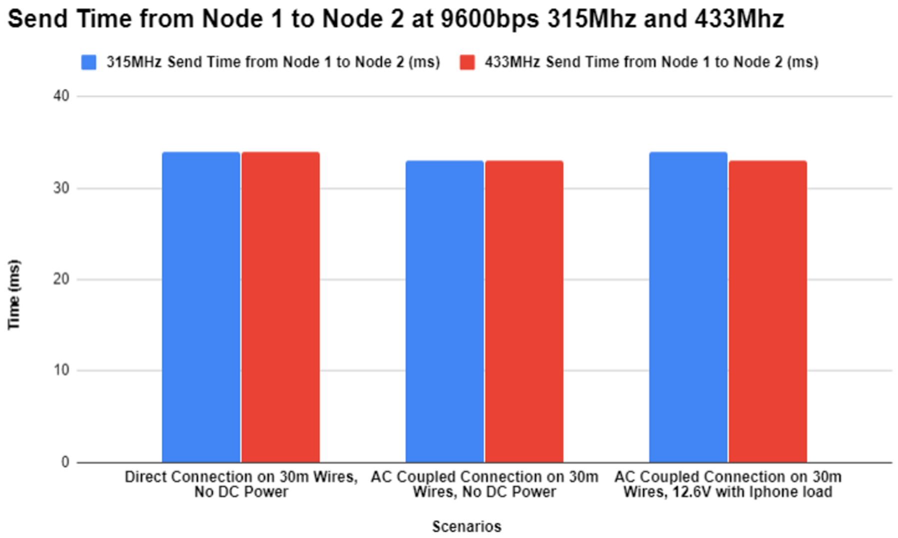




Testing

Results - From the Send Time to ACK Time

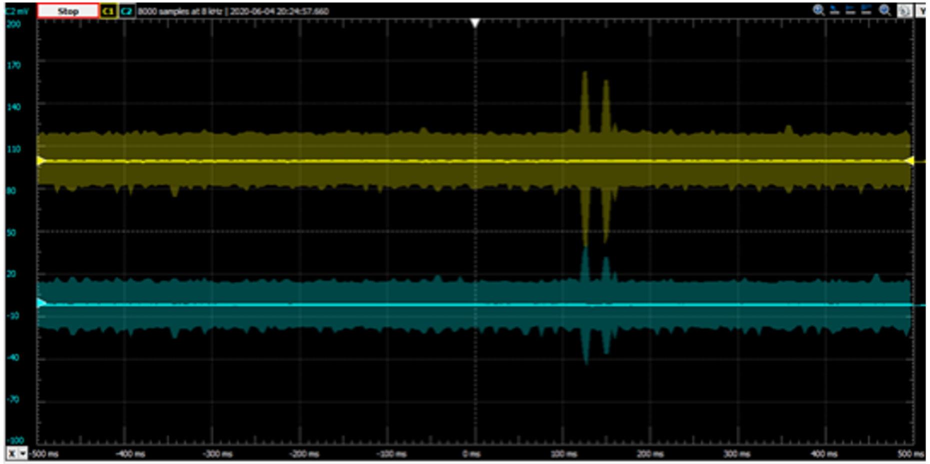




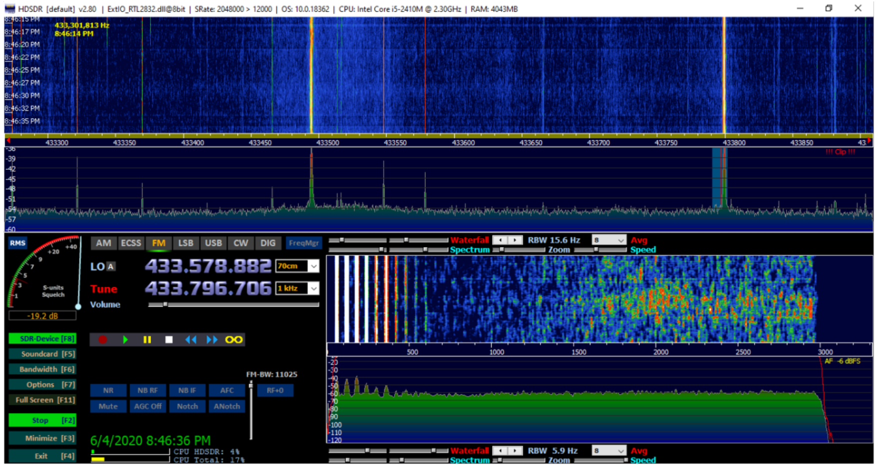
Testing

Results - Confirming the Signal at Both Nodes with DISC Analog Module

Signal at the Transmit and Receive Node in Real Time



Confirming the RSSI Values in Real Time with SDR Dongle



Difficulties

- Not being able to safely test the system specifications at higher voltages.
- Lack of dummy loads and laboratory space.
- Limited availability of parts.
- Due to these challenging times, the team was restricted to what we could test.

Future Work – when we have lab access again

- Develop the physical model
- Test using better measuring equipment
- Minimize EMI (Electrical Magnetic Interference) Radiation coming out of the system
- System integration of the power system monitoring and switching with in-band communications, e.g. INA219 connected on SPI bus, same as used for RFM69CW
- Operate the system at higher voltages (e.g. up to 48v) and variety of loads
- Find a better-suited microcontroller