IoTeam

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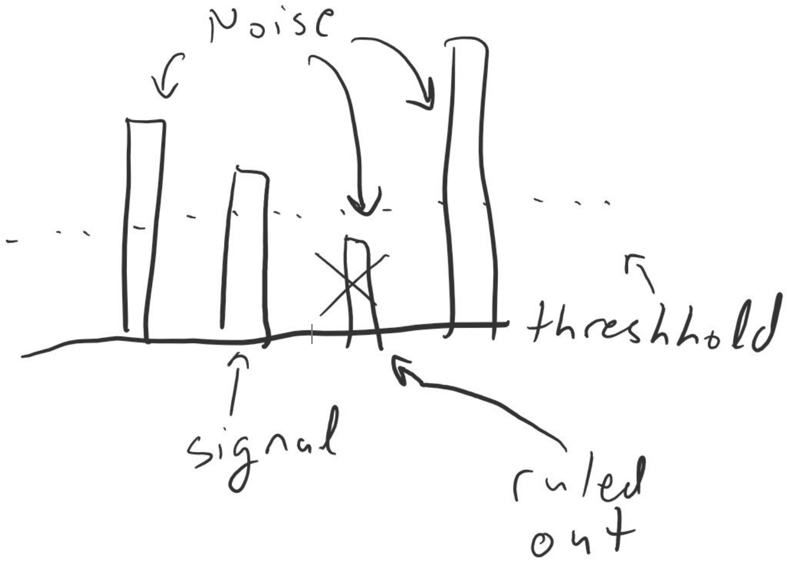
Robust FFT

- Jamal suggested we wait for a **repeat** reading for **robustness.**
- **Rule out frequencies** that drastically change in magnitude



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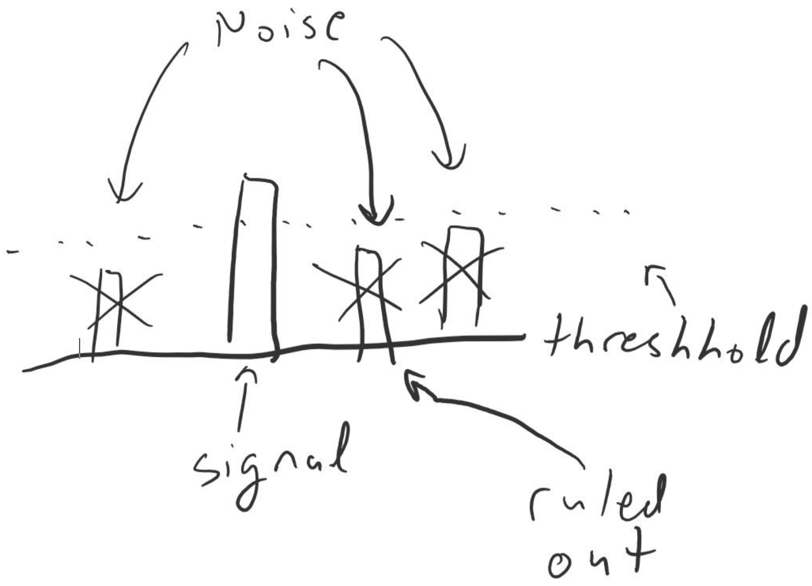
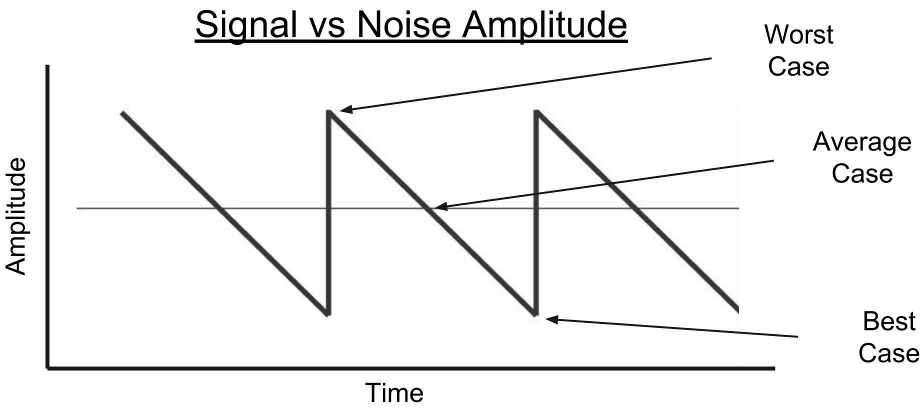


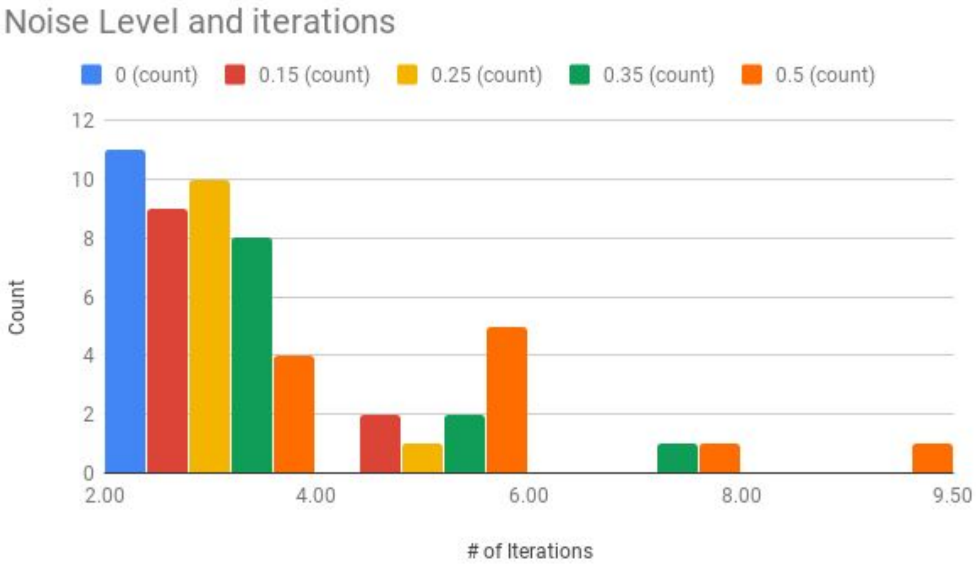
Robust FFT

- Worst Case: ~4 FFTs
- Average Case: ~2 FFTs
- Best Case: ~2 FFTs



Robust FFT

- Worst Case: ~9 FFTs
- Average Case: ~4 FFTs
- Best Case: ~2 FFTs



Robust FFT

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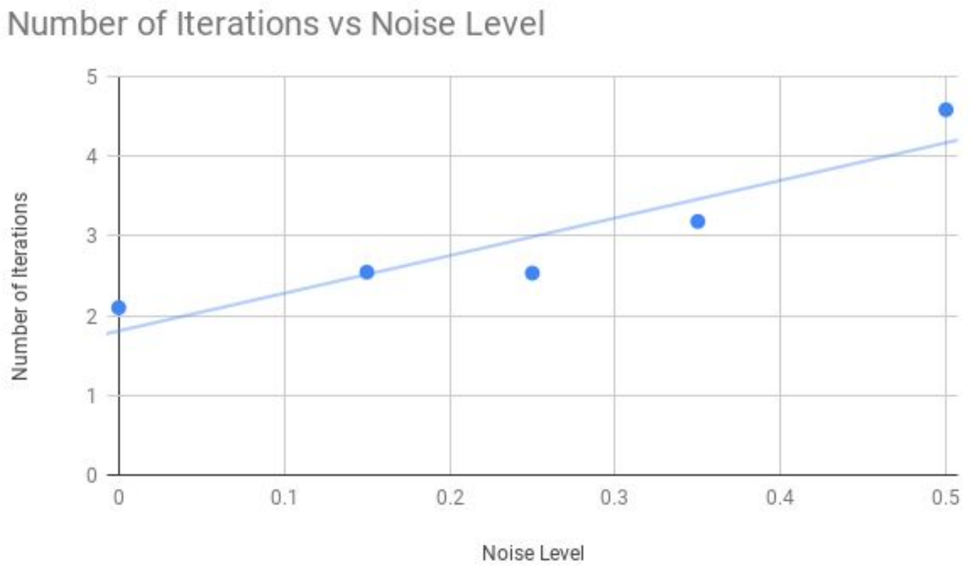
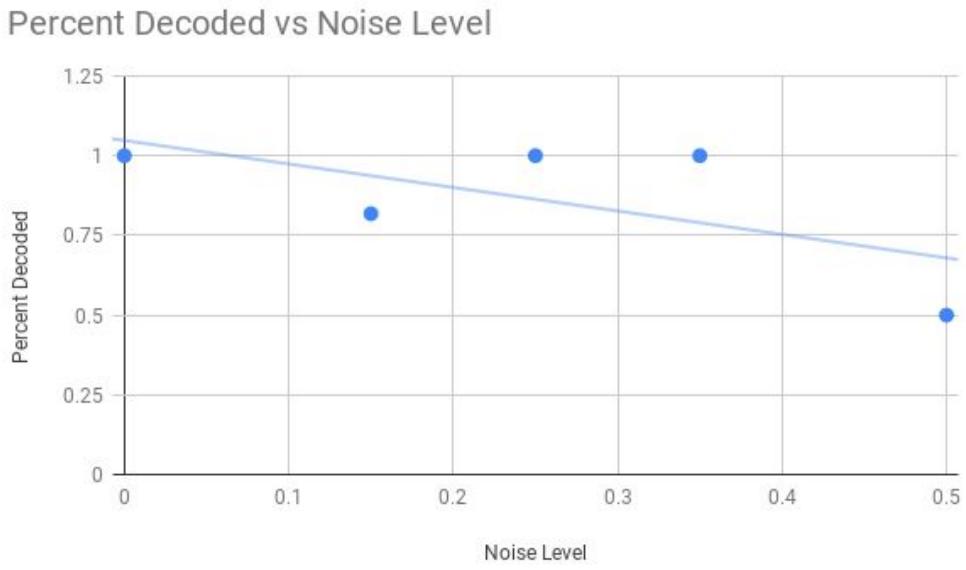


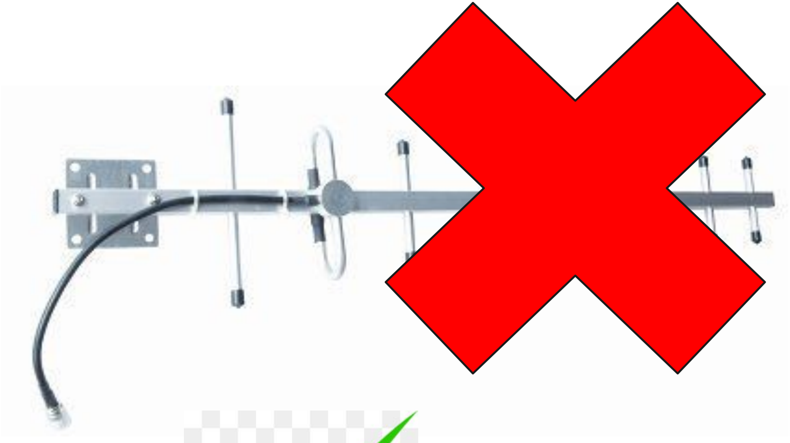
Robust FFT

- Worst Case: 50% decoded
- Average Case: 80-100% decoded
- Best Case: 100% decoded



Overcoming Interference

- Data-Driven Approach:
    - KISS
    - Don’t build antennas needlessly!
    - Quantify Theoretical Improvement first!



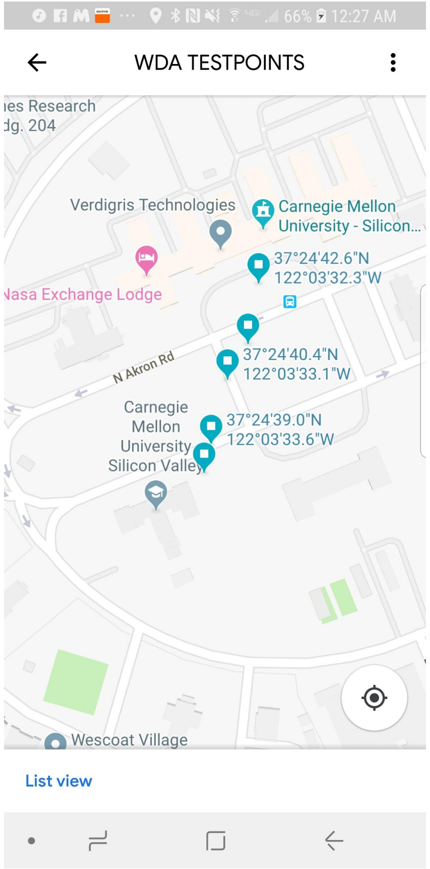
Mimicking Antenna Effect

WDA TESTPOINTS

			LOCATION FROM CMIL LAB		CMIL LAB	
Distance (m)	FSPL (db)	Antenna Eq(db)	Lat1	Long1	Lat2	Long2
240	73.272	3+0	37.412129	-122.05886	37.410056	-122.05952
190	71.243	3+2	37.411824	-122.05896	37.410056	-122.05952
150	69.475	3+4	37.411453	-122.059042	37.410056	-122.05952
120	67.2520468	3+6	37.411234	-122.0592	37.410056	-122.05952
95	65.22222	3+8	37.410832	-122.059327	37.410056	-122.05952
75	63.16964715	3+10	37.410662	-122.059381	37.410056	-122.05952

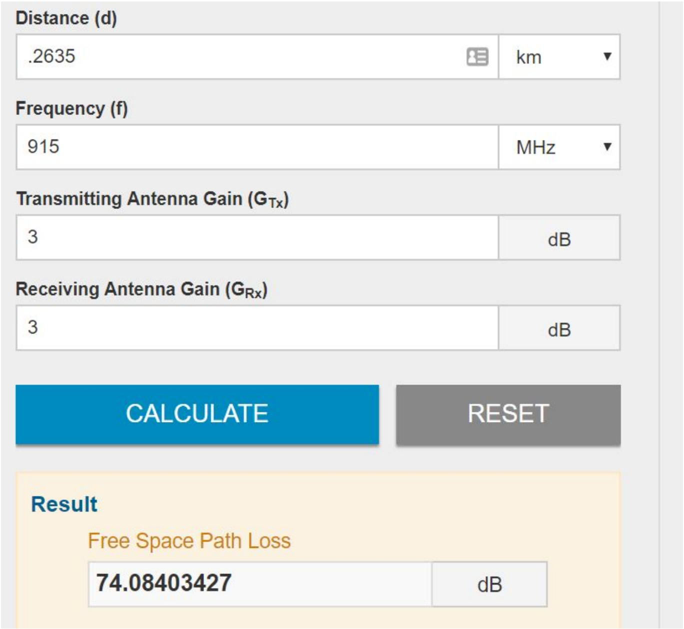
Overcoming Interference

- Base Case: 98% success at TX Power 6
- Squares are the physical locations tested to simulate an antenna of certain gain.



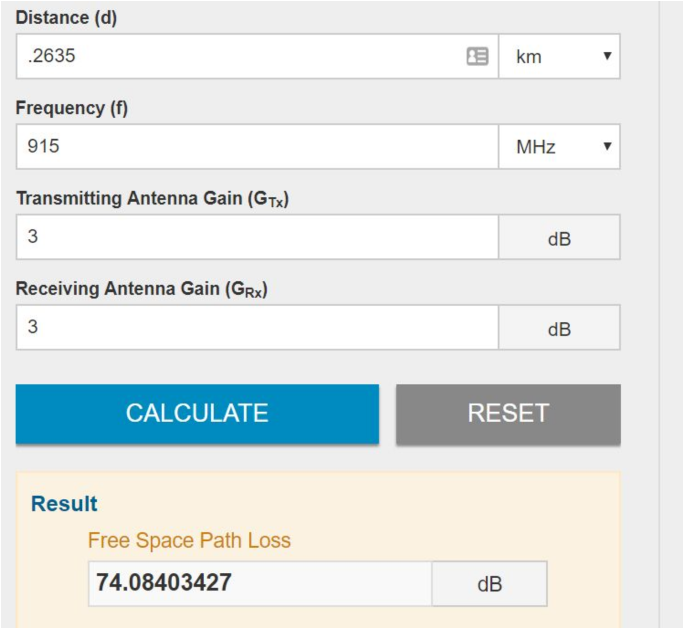
Overcoming Interference

- Base Case: 98% success at TX Power 6
- Theoretical Worst Case: Interferer right next to receiver and transmitter .2635 km away (-74 dB disadvantage)
- Success Rate: ~75%!



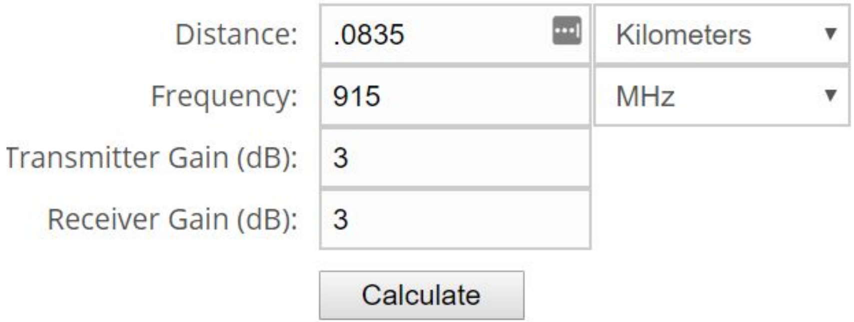
Overcoming Interference

- Real Scenario: Both Interferer and Receiver .2635 km away (0 dB advantage)
- Success Rate: ~88%!



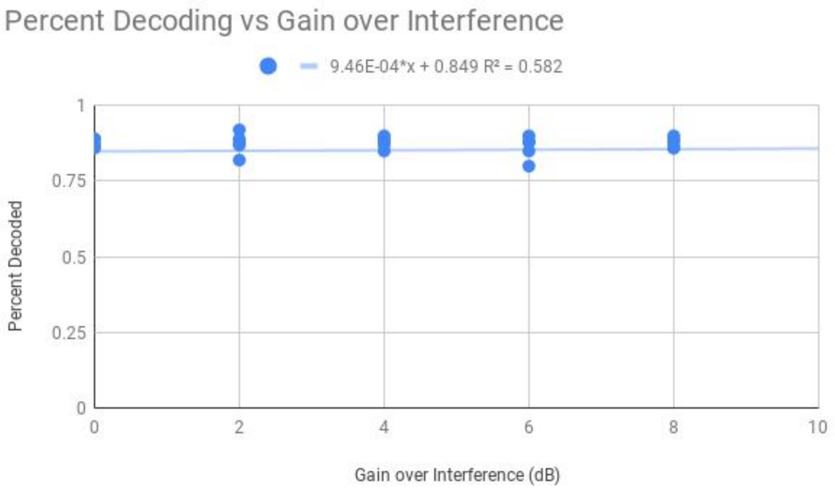
Overcoming Interference

- Assuming a 10 dB advantage: Interferer - 0.24 km away and transmitter - 0.8km away (10 dB advantage)
- Success Rate: ~87%!



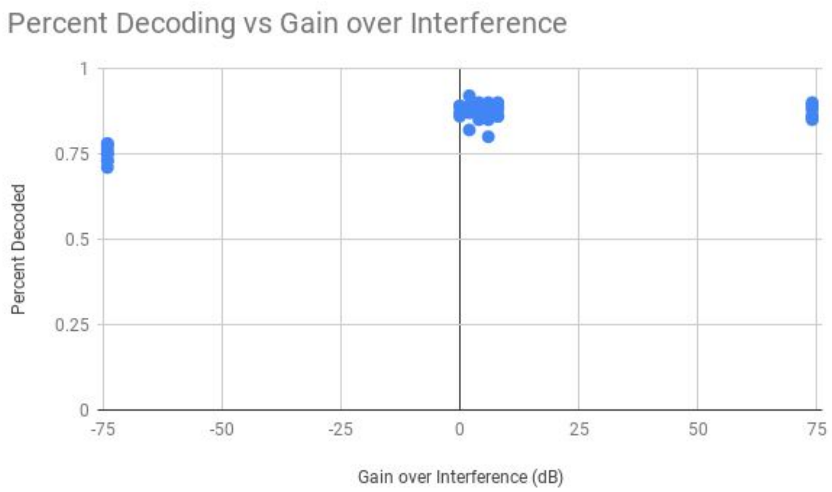
Overcoming Interference

- Adding an antenna provides no measurable improvement!
- Slope is effectively 0!
- Effectiveness of LoRa protocol allows packet to squeeze through
- Interferer always succeeds in interfering.



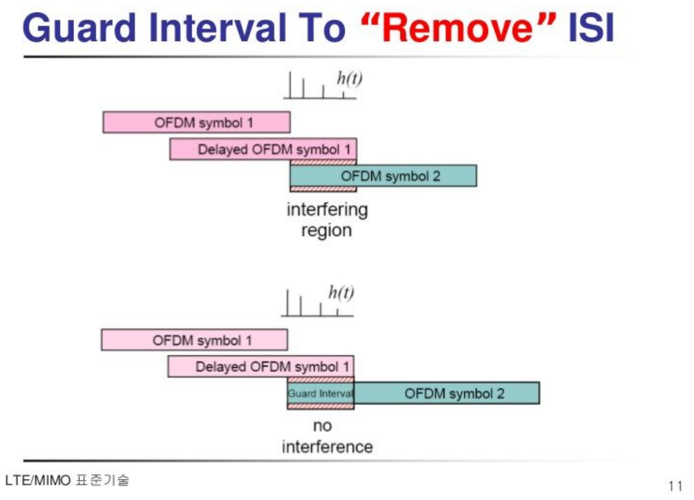
Overcoming Interference

- Even when transmitter is next to receiver and interference is .26 km away, same error rate.
- Only outlier is if interference is next to receiver, with 75% error rate.



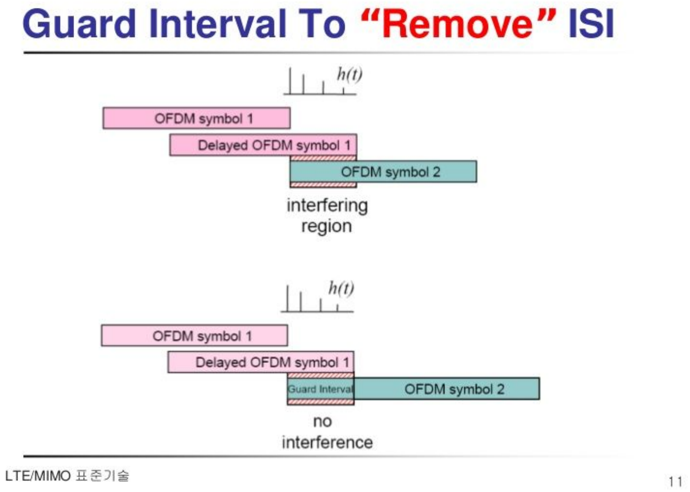
RSSI Advantage has little effect for LoRa

- Antenna => Marginal Improvements
- One extra packet is negligible (<1% increase in energy)
- Extra time is within socket timing error
- Timing plays a large role



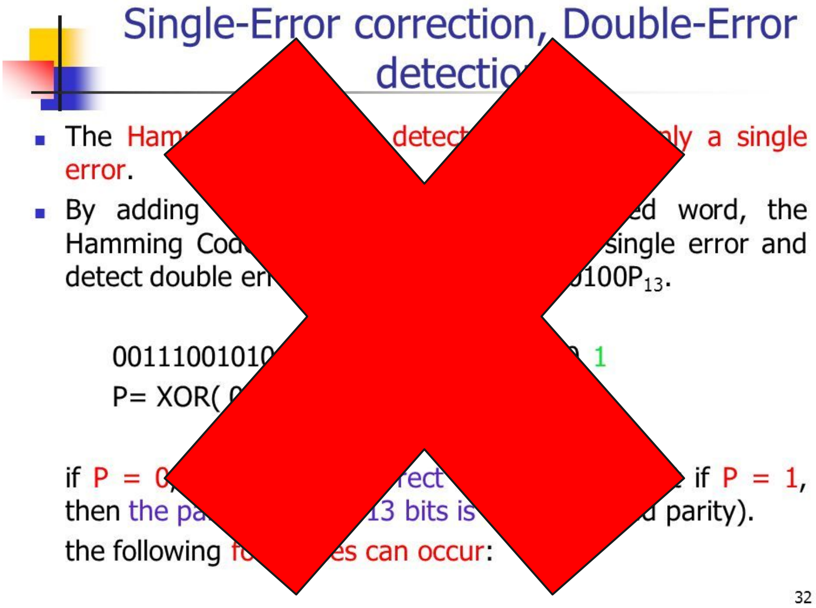
Timing the Packets

- Must send packets at a faster rate than interferer
- If interferer sends at 10 Hz, then sending at 20 Hz will guarantee one slips between within two sends.



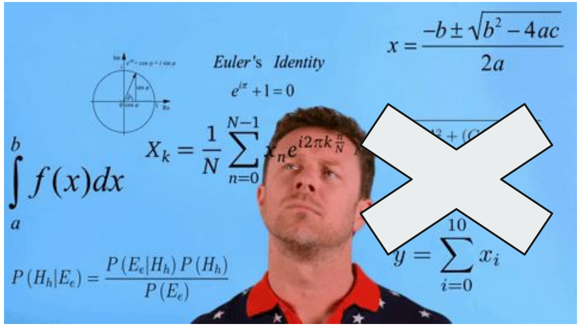
Timing the Packets

- Small packet => all or nothing corruption
- No need for bit error detection and correction

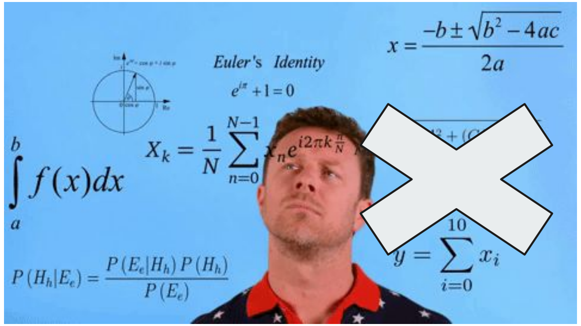


Say NO to Encryption Libraries

- RSA requires MINIMUM 1024 bits
- Large Headers in encrypted blocks
- **Unnecessary complexity**
- Unnecessary to maintain secrecy, only **authentication**



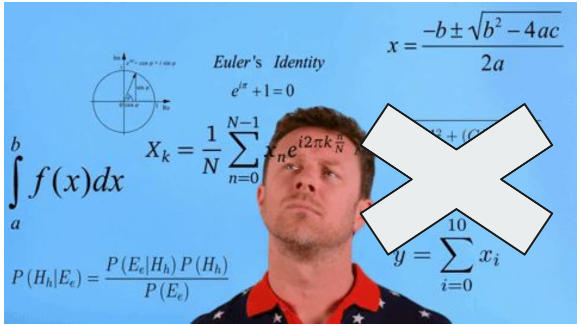
Packet Validation



- Frequencies in packet are delimited using '~' character.
    - Ex: 5800~400
- Encryption: XOR with **5 byte password**
- Any packets that aren't in the correct form after decryption are discarded by receiver
- One time pad is valid since data is sent faster than interferer has time to learn XOR value.

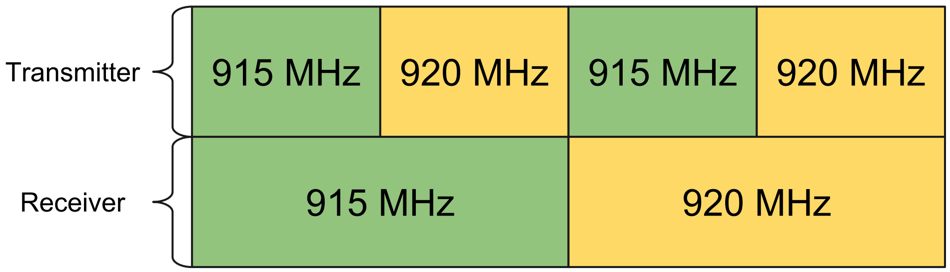
Challenges

- If XORing a byte results in 0, then LoRa.print terminates at the null character (1.5% chance)
- 1/256 chance attacker can impersonate '~' identifier



Frequency Hopping

- Jump between 915 and 920 MHz using LoRa.setfrequency()
- No extra power consumption
- Receiver jumps at 5 Hz speed
- Transmitter jumps at 10 Hz speed
- When frequencies align, transmission is successful
- No need for synchronization



Minimizing Packet Size

- Frequency range for competition went from 200 Hz to 19 KHz
    - Use **2 byte shorts**, not 4 byte floats
- Explored possibility of creating a **custom 12 bit floating point** representation
    - Would have reduced payload to 3 bytes
    - Could not maintain +/- 10 Hz error at high frequencies

Key Decisions

- 5 byte XOR encryption. Accept 1.5% risk of bad XOR.
- Get 2 FFT matches. In practice, high probability.
- Send 8 LoRa packets. Radio Power is cheap relative to Processor Power.
- Chose not to make an antenna.

Future Experiments

- Guarantee that no XOR results in 0.
- Reduce payload to 4 bytes.
- Use custom 4 byte RSA.
- Understand the outlier: Interferer distance has effect when right next to receiver, otherwise no effect.