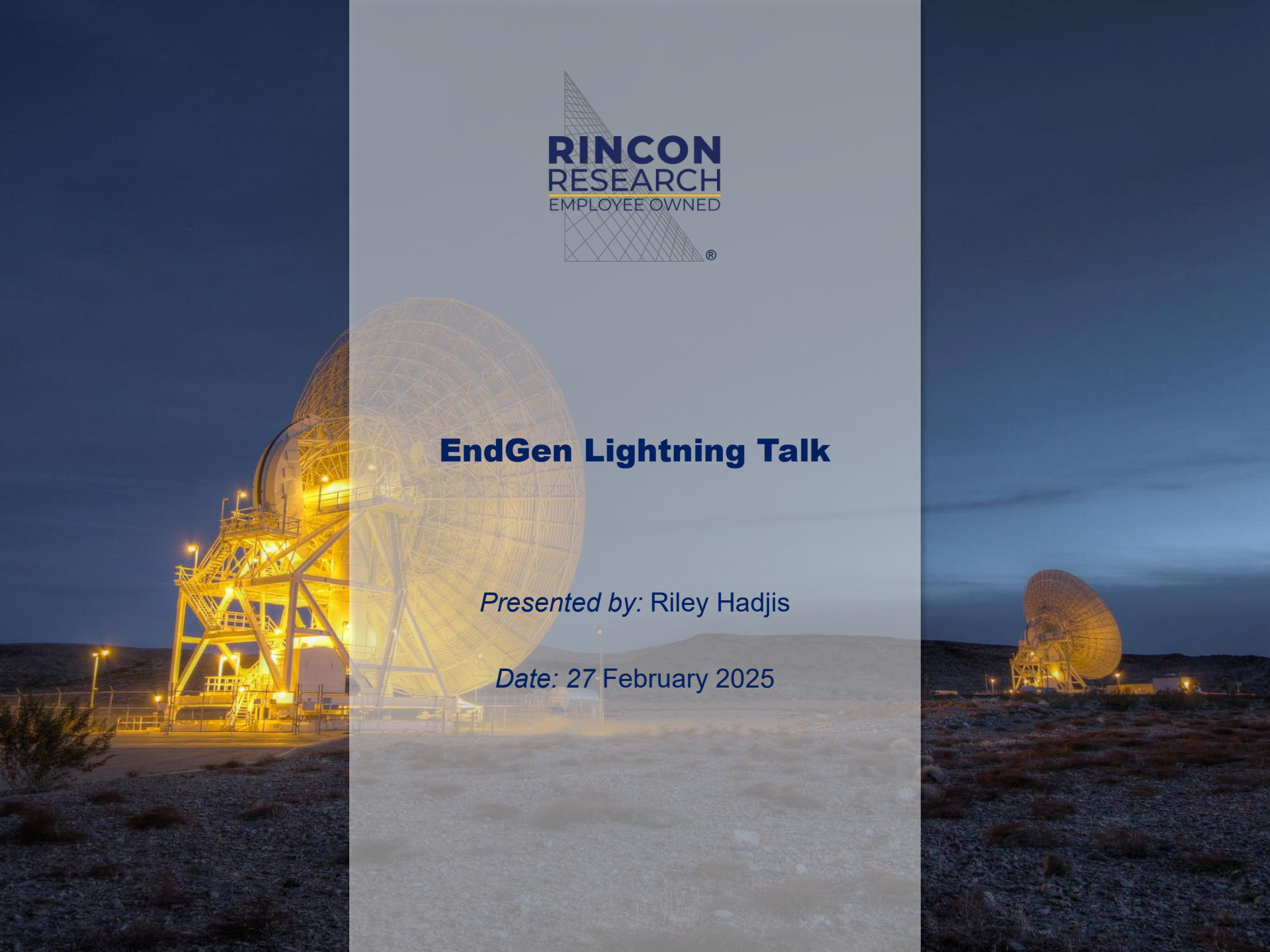

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EndGen Lightning Talk

Presented by: Riley Hadjis

Date: 27 February 2025

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End Gen BLUF

- Under an Internal Research and Development program, Rincon has developed an automated Radio Frequency (RF) waveform development framework called Catfish
- Catfish relied on a simple Reinforcement Learning (RL) framework with a small fully connected Neural Network to select waveform parameters
- Catfish was successful but limited
  - A small parameter space meant the possible waveforms were limited
- Generative Artificial Intelligence (GAI) has seen many recent advancements like Diffusion Models and Model Distillation
- These improvements can applied to a RL framework to efficiently develop new waveforms

Rincon believes that a Diffusion Model combined with Reinforcement Learning (RL) can generate tailored mission waveforms

Rincon Research Corporation

- **VISION:**
  To be the company of passionate, committed innovators that change the world.

- **MISSION:**
  We enable freedom and prosperity through technology.

- **VALUES:**
  Mission – The mission is our focus. Our customers' successes are ours!
  Excellence – We take the long term view and strive for excellence in everything we do.
  Integrity – We respect and are honest with ourselves, our customers, and our competitors. We cooperate with other companies and compete fairly.
  Loyalty – Good customers, employees, and teammates are to be cultivated and given the loyalty they deserve.
  Creativity & Innovation – We embrace creativity, innovation, and reasonable risk taking. We invest in our employees, research, and technology to be prepared for change.

- Founded in 1983 by Dr. Michael Parker, a 2011 NRO Pioneer inductee, we serve the intelligence and defense communities
- 300+ employees in strategic locations
- Worldwide staffing presence supporting on-site customer requirements

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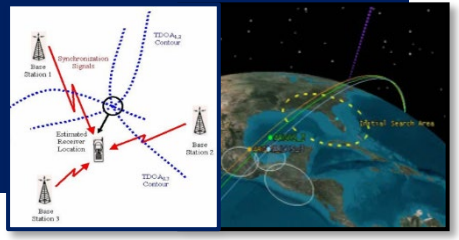
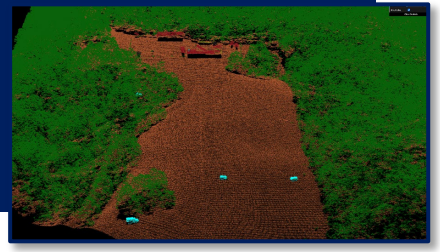
Technology Interest Areas

Geolocation/Tracking



Data Visualization

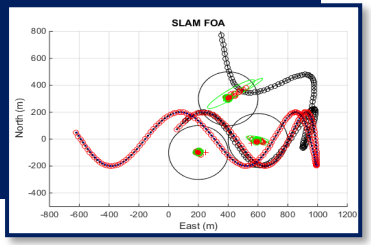
LiDAR



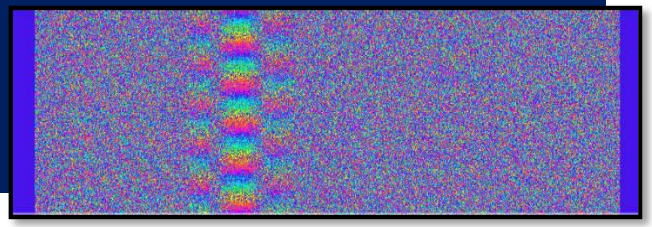
Machine Learning

RF Propagation

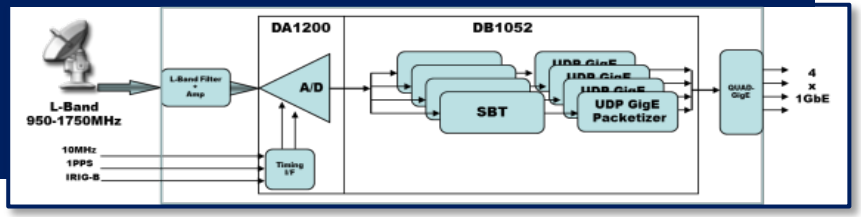
Enhanced Navigation



Novel DSP Techniques



Satellite and Terrestrial Communications



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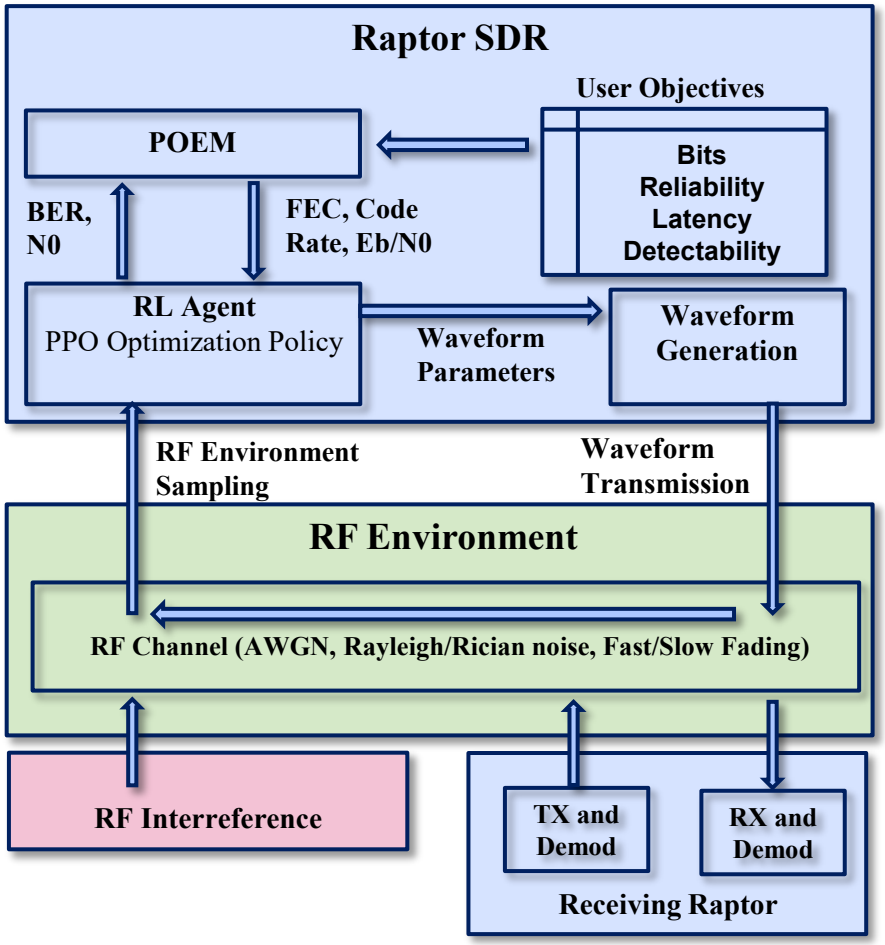
Catfish Background

- Rincon developed an AI/ML waveform generation tool known as Catfish
- It used RL to select waveform parameters such as carrier frequency, modulation scheme, data rate, etc
- We combined it with another Rincon developed tool: Pareto Optimal Embedded Modulator (POEM)
- POEM calculated the optimal code rate and FEC such that the waveform met user objectives
- Catfish was successful in simulation and is currently being implemented on an SDR
- However, it's range of novel waveforms is limited
- The ideas developed in Catfish can be extended to meet the goals of EndGen



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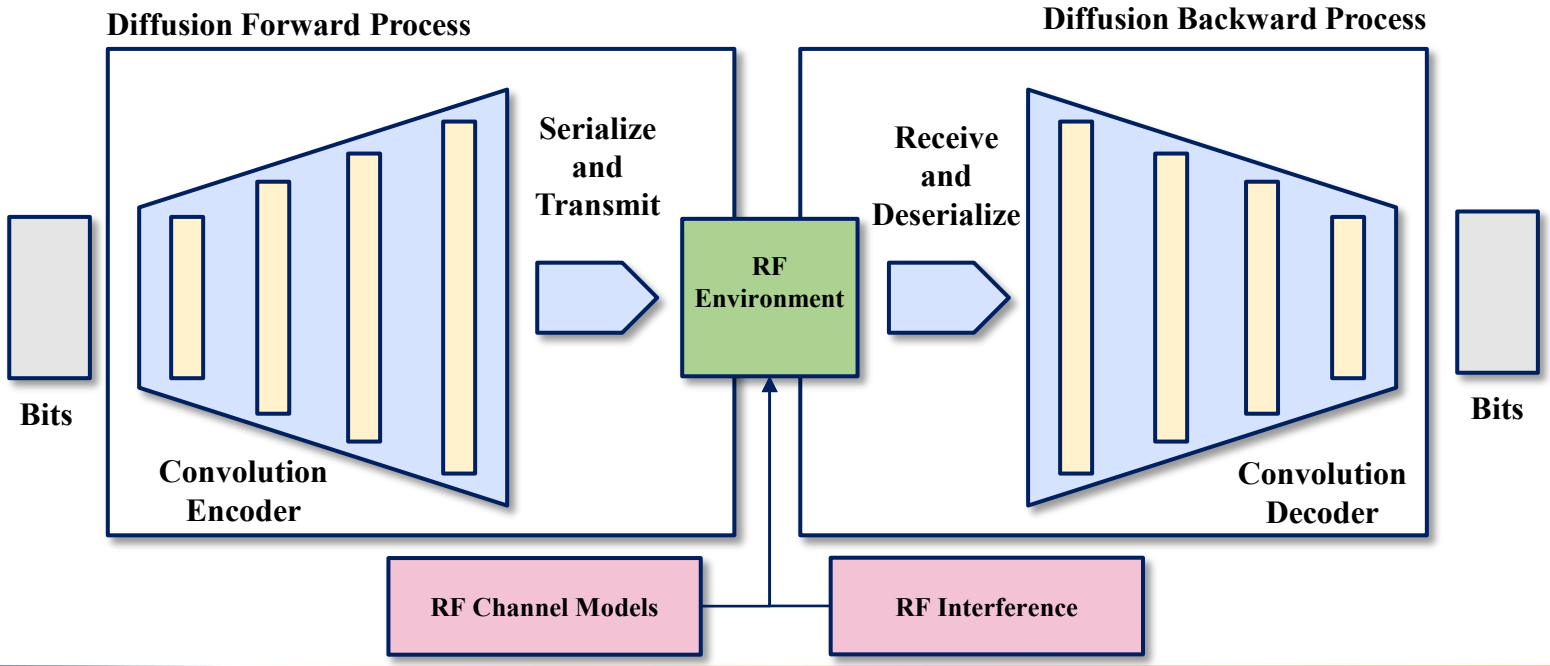
Ex-Situ Development

- A modern diffusion model's forward process can be extended to learn to "whiten" a time-band allocation instead of the normal static diffusion process
  - By whitening a time-band allocation, the model can learn to compensate for non-white RF channels
  - This will generate novel waveforms directly that are tailored to any RF environment
  - This can be used with human objective inputs such as bandwidth, time, power, throughput
  - A standard backward diffusion model is used to decode the generated waveform
  - An estimate or sample of the RF environment is needed
- Borrowing from Catfish, this operation can be learned over a wide range of RF environments automatically with RL
- Create "starting points" for in-situ learning or waveforms to be used on their own



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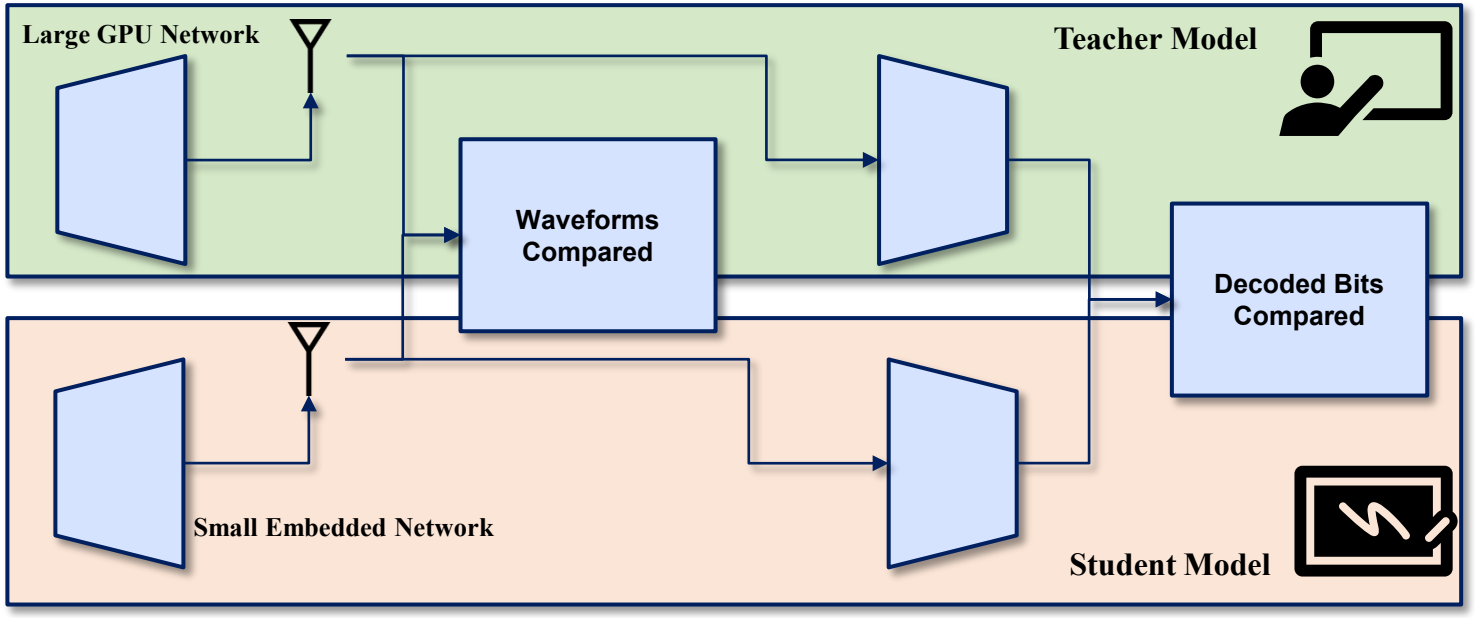
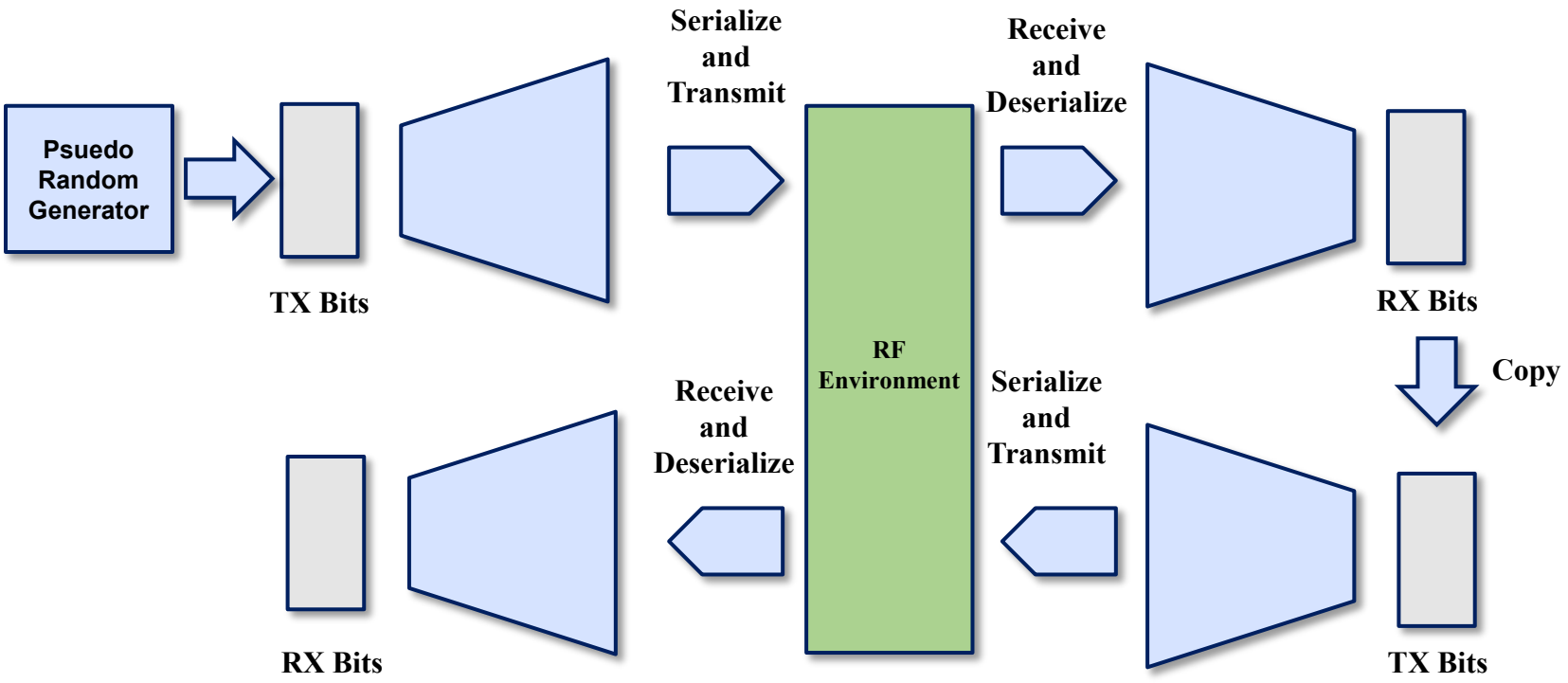
Ex-Situ Deployment

- Model distillation has been used to decrease the large parameter space of diffusion models
- Employing the large model as the “teacher” a smaller simpler model, the “student”, can be created
- The student model can even be hardware specific and taught with a hardware-in-the-loop benchtop setup
  - This allows for custom models for restricted hardware like FPGA’s and small microcontrollers
  - Furthermore a wide range of SDR front ends can be learned and performance optimized



In-Situ Deployment

- For in-situ deployment, learning can be based off of a known pseudo random bit sequence along with local RF measurements
- A bi-directional link would be learned as the models generate waveforms until one is found that meets some human objectives
- This requires two diffusion models learned through a RL process



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