Project Milestone Sheet

Secure & Robust Spectrum Sensing for Industry 5.0 using Realistic 1-Bit IRS

Project Elective – Spring 2026

Project Theme: Simulating a smart factory environment where a "Low-Cost" Intelligent Reflecting Surface (IRS) assists secure robot communication, explicitly addressing blockage and realistic hardware limitations (1-bit quantization).

Key Objectives:

- Transition from ideal theory to **realistic hardware simulation**.
- Implement **data-driven sensing** using codebooks.
- Ensure **secure communication** against eavesdroppers.

Wk	Dates	Milestone	Description & References	Deliverable
PHASE 1: The “Realistic” Foundation (Hardware Constraints)				
1	Jan 19–25	**Realism Check**	Review *Industry 5.0* context [Paper 1]. Study *Paper W1* to understand real IRS hardware (PIN diodes, 1-bit quantization, amplitude loss).	1-page Summary: "Ideal vs. Real IRS Constraints."
2	Jan 26–Feb 1	**The “1-Bit” Channel**	Code the channel model in Python. Restrict phase shifts to discrete states $(0°, 180°)$ instead of continuous values [Ref: Paper W1, Eq. 8].	Script: Channel sim with discrete phases.
3	Feb 2–8	**The “Dumbbell” Model**	Implement the "Dumbbell" unit cell response. Model the amplitude dip (signal loss) that occurs during phase switching [Ref: Paper W1, Fig 11].	Plot: `Reflection Amp vs. Freq` showing the dip.
PHASE 2: Data-Driven Sensing (Datasets & ML)				
4	Feb 9–15	**Codebook Design**	Create a “Codebook” of pre-set beam patterns (DFT or Random) instead of complex optimization [Ref: Paper W2].	`codebook.csv` with 32 predefined phase matrices.
5	Feb 16–22	**Smart Selection**	Implement “Beam Sweeping.” The sensor iterates through the codebook to find the pattern yielding the strongest RSRP.	Sim Result: `Received Power vs. Codebook Index`.

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6	Feb 23–Mar 1	**Buffer / ML Prep**	Buffer week. Optional: Explore "Absorption Mode" from [Paper W2] or start reviewing CNN architectures for the next step.	Mid-term status check.
7	Mar 2–8	**The ML Upgrade**	Train a simple DNN (3 layers, 16 neurons) to predict radiation patterns, replicating the experiment in [Paper W2, Fig 5].	Trained `.pth` or `.h5` model.
PHASE 3: Security & Optimization (The Twist)				
8	Mar 9–15	**Enter Eve**	Introduce an Eavesdropper (Eve) attempting to intercept data. Implement the Secrecy Rate formula from [Paper 3, Eq 12].	Updated sim with Eve's SNR calculation.
9	Mar 16–22	**Secure Beam**	Modify Codebook Selection. Pick the pattern that maximizes $(C_{user} - C_{eve})$ rather than just C_{user}.	Plot: `Secrecy Rate` (Naive vs. Optimized).
10	Mar 23–29	**Decentralized Twist**	Implement "Partial Observation" logic (sensor sees only part of the band) [Ref: Paper 2]. Use the ML model to infer missing data.	Script handling fragmented spectrum data.
11	Mar 30–Apr 5	**Robustness Test**	**Crucial Step:** Test "Secure Beam" performance under measurement noise [Paper W2] and imperfect CSI [Paper 3].	Graph: `Accuracy vs. Noise Level.`
PHASE 4: Wrapping Up (Results & Report)				
12	Apr 6–12	**The Money Plot**	Compare **Ideal IRS** (Continuous Phase) vs. **Your IRS** (1-Bit, Quantized). Prove practical feasibility.	Final Figures for Report.
13	Apr 13–19	**Drafting: System**	Write "System Model." Cite [Paper W1] for hardware design and [Paper W2] for measurement methodology.	Draft Chapters 1–3.
14	Apr 20–26	**Drafting: Results**	Write "Results." Highlight how ML ([Paper 2]) helps overcome hardware limits ([Paper W1]).	Full Report Draft.
15	Apr 27–May 3	**Final Presentation**	Prepare slides. **Hook:** "Theory assumes IRS is perfect; I simulated reality."	**Project Completed.**