



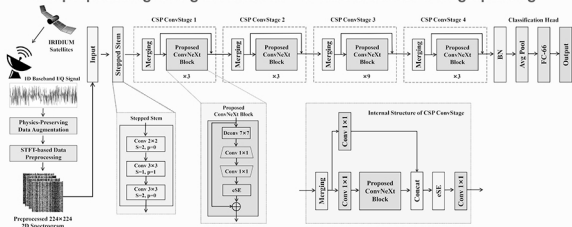
Background

1. Rapid expansion of LEO satellite constellations
2. Open space-to-ground links vulnerable to spoofing and unauthorized access [1]
3. Physical-layer authentication as a lightweight security complement
4. RF fingerprints from transmitter-specific hardware impairments

Challenges and Research Gap

1. Dynamic LEO channels with Doppler shifts and fading effects
2. Existing DL-based methods limited by accuracy and efficiency trade-offs [2]
3. Heavy architectures unsuitable for power-constrained LEO deployment
4. Vision-style patch processing disrupting RF time-frequency continuity

The proposed lightweight framework for LEO satellite RF fingerprinting



Performance Evaluation

TABLE I
PERFORMANCE COMPARISON OF DIFFERENT METHODS. THE BEST RESULTS ARE HIGHLIGHTED IN BOLD.

Metric	Proposed	ComNeXt-Base	ComNeXt-Small	ComNeXt-Tiny	ResNet-18 [3], [4]	VIT [6]	VGG16 [2]
Accuracy	99.51%	95.81%	97.19%	93.26%	93.84%	89.38%	85.71%
Precision	99.51%	95.84%	97.17%	93.36%	93.81%	89.41%	85.72%
Recall	99.48%	95.83%	97.20%	93.27%	93.74%	89.33%	85.63%
F1-Score	99.49%	95.81%	97.17%	93.27%	93.75%	89.32%	85.64%

TABLE II
COMPUTATIONAL COMPLEXITY AND EFFICIENCY COMPARISON (BATCH SIZE = 64).

Metric	Proposed	ComNeXt-Base	ComNeXt-Small	ComNeXt-Tiny	ResNet-18 [3], [4]	VIT [6]	VGG16 [2]
Parameters (M)	12.29	87.61	49.49	27.86	11.21	21.60	134.53
FLOPs (G)	2.05	15.37	8.70	5.46	1.82	4.24	15.47
Run Time (ms)	0.21	1.89	1.10	0.62	0.08	0.59	1.13
Memory (MB)	769.01	1548.60	1063.86	981.33	573.26	443.62	2912.63

TABLE III
ABLATION STUDY OF THE PROPOSED COMPONENTS.

Metric	Proposed	w/o STEM	w/o eSE	w/o CSP	w/o All
Accuracy	99.51%	97.49%	96.93%	97.36%	93.31%
Precision	99.51%	97.47%	96.88%	97.38%	93.45%
Recall	99.48%	97.49%	96.91%	97.32%	93.32%
F1-Score	99.49%	97.39%	96.89%	97.34%	93.35%
Parameters	12.29 M	12.24 M	10.69 M	55.17 M	49.36 M

