

## From Identification to Sensing: Physics-Consistent Activity Recognition Using Passive UHF RFID

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*Mots clés : RFID UHF passive, Reconnaissance d'action, Classification de séries temporelles*

*Keywords : Passive UHF RFID, Human activity recognition, Time series classification*

### Abstract

Passive radio frequency identification (RFID) systems operating in UHF band are primarily designed for identification, yet their backscattered signals are strongly shaped by electromagnetic propagation and environmental dynamics. This work explores passive RFID tags as opportunistic electromagnetic probes for privacy-preserving human activity sensing, with an emphasis on physically consistent observability and lightweight learning under limited data. This is particularly relevant for older adults, where changes in posture, mobility, and inactivity may indicate early functional decline.

We adopt a bi-static channel perspective in which human presence and motion perturb the effective reader-tag propagation through absorption, shadowing, scattering, and multipath geometry changes. Standard reader outputs representing signal strength (RSSI) and phase of backscattered signals can therefore be interpreted as indirect measurements of attenuation and micro-displacements[1]. Because raw phase is contaminated by protocol/hardware artifacts (frequency hopping, wrapping), we apply a lightweight physics-aware calibration[1] to preserve physical meaning: phase unwrapping for temporal continuity, per-frequency phase offset compensation using a static reference, and per-tag RSSI normalization.

To establish feasibility with minimal model complexity, we evaluate a pilot baseline combining MiniRocket[2] algorithm for feature extraction on calibrated RSSI/phase windows and logistic regression for classification. This avoids high-capacity deep models while still capturing informative temporal structure, suited to limited data.

Experiments in an instrumented office with multiple passive tags distributed on furniture and walls consider four coarse activity states: standing at desk 1, seated at desk 1, seated at desk 2, and empty room. On a held-out set from a separate session, the MiniRocket + logistic regression baseline achieves 70.1% accuracy and  $\approx 70.4\%$  macro-F1. Errors mainly occur between seated and standing at the same desk, whereas seated-at-desk-2 is better recognized. This is physically consistent: posture changes at a fixed location induce subtler channel perturbations than location changes, and separability depends on whether dominant direct paths intersect body regions.

These results suggest two directions: (i) treating tag placement as a sensing design variable to improve posture observability by amplifying shadowing and phase variation, and (ii) fusing generic temporal embeddings with physically interpretable descriptors derived from calibrated RSSI/phase (e.g., shadowing index, RMS phase variation, channel coherence, read-rate visibility, spatial entropy) to improve robustness and interpretability. Overall, the work aligns with physics-guided AI for intelligent radio sensing by combining channel-aware calibration, lightweight learning, and placement-aware observability for privacy-preserving activity recognition with passive RFID.

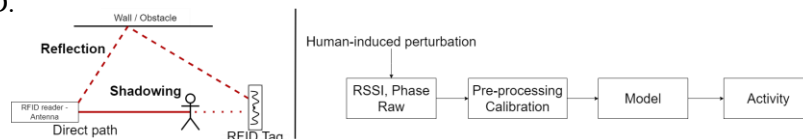


Figure 1: Passive UHF RFID sensing principle and processing pipeline from raw RSSI/phase to activity.

### References

- [1] X. Fan *et al.*, “Multiple Object Activity Identification Using RFIDs: A Multipath-Aware Deep Learning Solution,” in *Proc. IEEE ICDCS*, 2018.
- [2] A. Dempster *et al.*, “MiniRocket: A Very Fast (Almost) Deterministic Transform for Time Series Classification,” in *Proc. ACM SIGKDD (KDD ’21)*, 2021.