EMILY : Electro Magnetic Interference Ledger & registrY

Gregory Hellbourg[(1)], Neal Patwari[(2)], and Ning Zhang[(3)]

[(1)] California Institute of Technology, Pasadena, CA, USA
[(2)] The University of Utah, Salt Lake City, UT, USA
[(3)] Washington University in St. Louis, St. Louis, MO, USA

***Abstract*—Radio-frequency interference (RFI) is a routine operational risk for radio astronomy and other passive services. Despite clear protection criteria and monitoring guidance in the ITU-R regulation [1], [2], incident reporting remains local and heterogeneous, limiting cross-site comparisons and trend awareness. EMILY, the *Electro Magnetic Interference Ledger & registrY*, is a lightweight, privacy-preserving system that helps observatories and agencies report, curate, and analyze interference in a consistent way.**

I. Motivation

Observatories increasingly encounter emissions from terrestrial and non-terrestrial networks near scientific bands. Thresholds for harmful interference are well established for radio astronomy [1], and spectrum monitoring methods are documented [2], yet each site logs incidents differently, uses different units and resolutions, and shares cautiously due to operational sensitivities. These differences make it hard to see whether a band is becoming busier across a region, whether diurnal patterns are shifting, or whether a new service is measurably changing the observing risk. In practice, an operator may never learn that a lawful change in duty cycle or bandwidth has doubled data loss at ground sites. Spaceborne experience with SMOS and SMAP in the protected $1.4\,\mathrm{GHz}$ band shows that consistent incident records enable triage and mitigation at scale [3], [4]. EMILY generalizes that lesson to ground systems by standardizing summaries and by preserving each site's control over detail.

II. Definitions and Scope

Under the ITU Radio Regulations, interference and harmful interference have precise meanings [5]. A radio telescope, however, treats any detectable emission in its receiving band as interference in the observational sense, even when the emission is lawful (e.g., licensed in-band service or compliant adjacent-band leakage). Telescopes also tune beyond protected bands allocated to scientific services for redshifted lines or continuum observations. Disruptive signals there are not inherently unlawful. EMILY records both perspectives: an observatory-impact view (center frequency, bandwidth, time window, level/PFD range, time signature, modulation hints) and a regulatory-context tag derived from allocation tables (e.g., Radio Astronomy Service (RAS) band, adjacent to RAS, other service in-band, spurious/unknown). EMILY is descriptive, not adjudicative. To capture change, incidents may be marked "new to site/band" and carry compact features such as duty cycle, bandwidth evolution, center-frequency drift, and cyclostationary components where applicable. These help surface trends even when emissions remain lawful.

III. Concept and Participation

EMILY is a secure website and API that accepts small, structured incident records, validates them, and produces privacy-aware analytics. A ledger model preserves an append-only history of each record so corrections add versions and prior entries remain auditable. Participation is open to observatories, spectrum teams, universities, and, under policy, operators and regulators. A site designates a contact and submits minimal metadata via web form or API. Optional automation converts regular flag outputs into incidents with minimal effort. Typical roles are: reporters (observers/technicians who submit incidents or review automated ones), site curators (who approve redaction settings and quality checks), and data consumers (astronomers planning observations, managers preparing reports, regulators and operators reviewing summaries).

IV. Data Collection and Normalization

Manual entry captures key parameters: UTC start/stop, telescope location (lat/lon), center frequency and bandwidth (Hz), and an intensity estimate (receiver power in PFD in $\mathrm{W\,m^{-2}\,Hz^{-1}}$ or Jansky). Optional fields describe time structure (continuous/transient), duty cycle, cyclostationary features, modulation hints, and receiver context. This pathway remains usable even without standard observatory exports.

Automated entry accommodates varied backends and formats. Lightweight adapters ingest local products (flag masks, spectra, QA logs) from single-dish or interferometric systems with diverse resolutions and cadences. Averages are used to estimate and subtract a baseline, and connected time–frequency regions are summarized with descriptors (center, bandwidth, time span, SNR, duty cycle, cyclostationary traits). Outputs in JSON/CSV are coerced to SI units; timestamps are in UTC and positions in WGS84. Syntax and semantic checks ensure validity, while deduplication suppresses redundant entries from repeated scans. Native resolution is preserved, and summaries stay comparable across instruments without regridding, in line with monitoring standards [1], [2]. Each record includes a method tag (e.g., "receiver power in dBm", "PFD") and optional uncertainty (e.g., $\pm 3\,\mathrm{dB}$, $\pm 1\,\mathrm{kHz}$ center).

V. Quality Control and Comparability

Because observatories differ in format and resolution, EMILY favors transparent comparison over forced uniformity. Basic checks verify units, monotonic time, plausible frequency ranges, and agreement with the instrument's declared band. Where two sites report coincident incidents in time/frequency, EMILY notes co-observation without implying causality. When computing summaries, it avoids rebinning raw measurements. Instead, it aggregates per-instrument statistics (e.g., clean-time fraction in native spectral resolution or time bins) and then forms ensemble indicators (median, interquartile range) across sites. Public dashboards clearly state the binning used for display so planners can interpret differences honestly. This posture preserves scientific integrity while still delivering actionable, comparable summaries.

VI. Privacy and Access

Privacy is field-level and opt-in. By default, EMILY publishes a coarse location tile, rounded time window, affected band, and aggregated level ranges. Exact coordinates/times and richer features remain restricted to roles the site designates (e.g., national regulator). Submissions are tied to organizations, not individuals. The append-only ledger provides accountability without exposing proprietary operations or sensitive scheduling. For community awareness, EMILY can expose band-level trend indices (e.g., quarterly change in clean-time) without linking to specific sites unless consent is granted.

VII. Historical and External Data

Many observatories maintain years of band scans, spectrograms, and flag masks. EMILY includes bulk-import tools that map legacy logs into incidents without moving raw data off-site. A backfill mode preserves original timestamps and marks imports as historical. Local redaction lets sites mask sensitive fields before upload. Where permitted, EMILY enriches incidents with transmitter registries, license databases, satellite ephemerides (to indicate satellites in view or boresight avoidance windows [6]), and field-monitor reports using the same schema, always honoring each submission's privacy choices and clearly indicating when enrichment was applied. These context layers help distinguish local emitters from wide-area or spaceborne sources, improving triage and regulatory dialogue.

VIII. Analytics and Use Cases

Contributors receive dashboards and APIs to answer practical questions. Clean-time percentages by band support deep-integration planning; occupancy vs. local hour reveals diurnal trends; frequency heat maps and PFD percentiles (e.g., P50, P90) quantify how often and how strongly bands are affected, enabling planning under uncertainty.

Selecting a site for a sensitive observation. An astronomer targeting $1400\,\mathrm{MHz}$ queries recent data at candidate telescopes. EMILY returns clean-time, diurnal occupancy, and P50/P90 metrics, revealing windows with low historical occupancy to guide site and schedule selection.

Triaging a new local interferer. A spectrum manager detects an emitter at $980\,\mathrm{MHz}$. EMILY compares recent weeks and neighboring sites to distinguish local from wide-area sources. Registry overlays narrow suspects, helping identify the likely transmitter with concrete evidence.

Assessing the impact of a new service. A regulator evaluates pre/post deployment effects using EMILY's clean-time, incident count, and strength percentiles over 90/180-day windows, following ITU-R practices [2] while preserving site confidentiality.

Verifying satellite mitigation. Satellite operators test boresight avoidance or power control. EMILY compares measurements across scenarios (e.g., no-avoidance vs. buffer zones), reporting attenuation, duty-cycle change, and residual leakage in an operator-neutral, quantitative framework.

IX. Limitations and Responsible Use

EMILY is not a compliance system and does not render legal judgments. Observationally disruptive signals may be lawful. Conversely, absence of reports is not proof of absence. Summaries reflect heterogeneous instruments and observing modes. Public charts should be read as risk indicators, not absolutes. When names or locations are sensitive, sites should use the default redaction. When a formal complaint is warranted, EMILY's records and small evidence artifacts can support dialogue with national regulators within the framework of RA.769 thresholds [1] and relevant monitoring guidance [2].

X. Conclusion

EMILY turns local, heterogeneous detections into a shared, privacy-preserving situational picture. Astronomers reduce data-loss risk by scheduling where bands are historically quiet. Spectrum managers remediate faster with context. Regulators gauge systemic impact with auditable summaries. Satellite operators validate mitigation. The approach respects institutional constraints while capturing the long-term history needed to steward shared spectrum.

References

[1] International Telecommunication Union, "Protection criteria used for radio astronomical measurements," *Recommendation ITU-R RA.769*, latest version.

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[5] International Telecommunication Union, *Radio Regulations*, Article 1 (Definitions), latest edition.

[6] Nhan, Bang D., et al. "Toward spectrum coexistence: first demonstration of the effectiveness of boresight avoidance between the NRAO green bank telescope and Starlink satellites." The Astrophysical Journal Letters 971.2 (2024): L49.