Report on status of RFI best practices in the area of DCS

Presented to CGMS-54 Working Group I session, agenda item 3.2

Coordination Group for Meteorological Satellites

Executive summary of the WP

This document outlines a comprehensive, lifecycle-based framework for managing Radio Frequency Interference (RFI) within satellite-based Data Collection Systems (DCS). It establishes that ensuring operational resilience is a strategic imperative that must be integrated from initial system design through ongoing operations, as a proactive design posture is the most effective and cost-efficient strategy for managing interference. The scope encompasses the end-to-end movement of data , organized into five key stages: planning, monitoring, characterization, mitigation, and removal. Central to these best practices are requirements for flexible hardware, such as reprogrammable transmitters and transparent transponders , alongside the utilization of AI/ML for advanced performance monitoring. Ultimately, the successful removal of RFI depends on both technical signal characterization and the cultivation of strong organizational relationships to influence change in RFI source operations.

Introduction & Scope

Objective: Define the framework for managing RFI throughout the DCS lifecycle.

Definition of RFI: Any human-caused (anthropogenic) or natural electromagnetic energy that negatively affects system performance.

Scope: End-to-end data movement—from terrestrial Data Collection Platforms (DCP) to terrestrial distribution systems via satellite relay.

Exclusions: Direct sensor interference, downstream distribution systems, and intentional/malicious disruption.

Planning for RFI in System Design

Communication Modeling:
Utilizing modified Shannon-Weaver models to identify RFI-vulnerable components.

The Design Window:
Satellite hardware and spectrum architecture must be finalized early; modifications post-launch are nearly impossible.

Proactive Acquisition:
DCS operators must be active in satellite acquisition to ensure RFI is factored into spectrum filing.

Recursive Effort:
Once a variable is addressed in one part of the chain, the impact on others must be assessed.

Technical Design Considerations

Transmitter Requirements:

- Must adhere to industry standards (spurious emissions, filtering).
- **Flexibility**: Designed for remote commanding (backhaul) and firmware updates to adapt to new RFI avoidance techniques without hardware changes.

Satellite & Receiver Resilience:

- **Selectivity**: Satellite receivers should maximize desired signals and exclude undesired ones.
- **Transparency**: Use transparent transponders so uplink signals can be analyzed via the downlink.
- **Metadata:** Ground stations should process signal strength, timing, and variability metadata for each message.

Monitoring System Operations

Categories of Monitoring:

1. **Supporting Infrastructure** performance.
2. **Data flow integrity** (identifying loss or corruption).
3. **Spectrum monitoring** (uplink/downlink) to confirm non-DCS RF energy.

Key Capabilities:

- **Automated dashboards** for real-time status.
- **Extended storage** for historical trend analysis.
- **Advanced Analytics:** Leveraging AI/ML to merge performance metrics with In-Phase **Quadrature (IQ) spectrum data.**

Characterizing RFI and Communicating Impact

Characterization Data: Aligning with ITU Satellite Interference Reporting and Resolution System (SIRRS) requirements.

Required Documentation:

- Source details (location and measured signal characteristics).
- Frequency assignments and scan/geolocation plots.

The Regulatory Reality: Unreported RFI is viewed as “no RFI” by regulatory bodies; documenting the specific impact on user operations is critical for support.

Mitigation Strategies

- **Mitigation vs. Removal:** Focused on limiting data loss while the RFI source is still active.

Operational Adjustments:

- Employing alternative broadcast times, redundant transmissions, or different channels.
- Repointing antennas or updating to modern, more robust DCP models.

Technological Improvements:

Improving digital signal processing and using error correction or robust modulation.

Data Path Redundancy:

Using multiple satellites or commercial services to avoid single points of failure.

Removing RFI & Organizational Relationships

Formal vs. Informal Approaches

RFI removal via regulatory enforcement onforcement or collaborative engagement.

The “Collaborative Approach”

International sources often unaware of interference.

Effective Strategies

Radio-operator engagement is fastest. Emphasize “Safety of Life & Property” impact.

Prerequisites for Removal

Clearly characterized signal & high certainty of operator identity.

Conclusion – A Strategic Imperative

Shift in Posture:

Move from reactive response to proactive, lifecycle-based management.

Cost-Efficiency:

Embedding monitoring and flexibility during the design phase is the most cost-effective RFI strategy.

Core Takeaway:

Reliable data integrity in a congested spectrum depends on robust technical design coupled with strong organizational relationships.

Key issues of relevance to CGMS:

- **Proactive Lifecycle Design and Spectrum Management:** Satellite hardware and spectrum architectures must be finalized early in the acquisition process because modifications post-launch are generally impossible.
- **Advanced Monitoring and AI Integration:** Fundamental system resilience requires the ability to distinguish between nominal and degraded performance through dedicated spectrum monitoring and the analysis of signal metadata.
- **Regulatory Engagement and Collaborative Relationships:** Technical characterization is only one part of the solution; successful RFI removal relies heavily on formal reporting to regulators and maintaining organizational relationships.
- **Reference to HLPP 2.2**

To be considered by CGMS:

- For endorsement by CMGS-54 Plenary as a DCS RFI Best Practice.