LIBERTY PLATFORM SOLUTIONS

Multi-Channel RF Record Application

MULTI-CHANNEL RF RECORD APPLICATION

Wideband, Frequency-Coherent, Phase-Coherent, Gapless Real-Time RF Capture & Metadata Extraction

Overview

Modern wireless, SATCOM, 5G/6G, radar, and configurable-EW systems require continuous, lossless, frequency-coherent and phase-coherent RF data capture across wide, dynamic environments. Traditional RF recorders rely on host buffering, non-deterministic storage, and limited alignment controls—resulting in data gaps, drift, skew, and inconsistent metadata.

The LIBERTY Multi-Channel RF Record Application (MC-RF-REC) provides deterministic, gapless multi-channel RF/IF recording using COTS Keysight PXIe/AXIe digitizers with optional Quonset Microwave QM-Series RF converters. Every sample is streamed, validated, time-stamped, coherently aligned, and stored with zero dropped data, enabling long-duration coherent ingest for commercial wireless, SATCOM, 5G/6G R&D, radar, phased arrays, EW/EMSO, and AI/ML waveform analysis.

Applications

Commercial Wireless
5G/6G FR1 & FR2 ingest, coexistence, MIMO, RF environment reconstruction.

SATCOM
L/S/C/X/Ku/Ka ingest, uplink/downlink monitoring, interference event reconstruction.

Antenna Test & Phased Arrays
Element-level ingest, coherent multi-channel capture, NF/FF/NFFF/CATR.

Configurable EW / EMSO
Wideband LPI/LPE ingest, multi-channel correlation, ingest for replay, AI/ML analysis.

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KEY FEATURES

Continuous Frequency Coverage: 10 kHz – 40 GHz
Via LIBERTY digitizers + QM1003, QM1004, and QM1040 RF converters.

Instantaneous Capture Bandwidth (Per Channel)
- 1 GHz (AXIe)
- 250–1000 MHz (PXIe)

Real-Time FPGA-Based Ingest Pipeline
- Deterministic real-time ingest, framing, validation, metadata extraction
- User-defined center frequency and capture bandwidth with sub-hertz resolution
- Real-time channel-health and alignment-status telemetry
- Multi-resolution full-rate and decimated data layers

Gapless, Zero-Loss Recording
- Guaranteed zero dropped samples
- FPGA-sequenced time stamping and packet verification
- Sustained multi-GB/s ingest
- Deterministic multi-channel coherence across all modes

Multi-Channel Frequency & Phase Coherence
- Frequency coherence: shared-LO architecture, < ±0.01 Hz drift
- Phase coherence: < ±0.5°
- Amplitude match: < ±0.5 dB
- Time skew: < ±0.5 ps
- Supports RF channel alignment across amplitude, phase, frequency, and skew
- Channels can be configured as independent, dependent, or partially independent
- Real-time monitoring of RF alignment factors, with validity/status indication for current operating. parameters
- Fully compatible with LIBERTY System Setup Application for automated multi-channel RF alignment

Measured Performance
- Differential amplitude: 0.0057 dB.
- Differential phase: 0.124°.
- Differential skew: 1.6×10^{-13} s.

Selectable Channel Count
4, 8, 16, 20+, or user-defined; supports coherent groups or independent channel partitions.

User-Selectable Data Format
- Complex (I/Q)
- Real (I-only)
- Real (Q-only)
- Stored as interleaved 16-bit I + 16-bit Q, or 16-bit Real

Embedded Metadata Header
Every recording includes a metadata-rich header documenting channel settings, alignment status, timestamps, reference sources, frequency/bandwidth parameters, data formats, and all acquisition conditions.

Decoupled Capture & Export Bandwidth
Record at full bandwidth while exporting/decimating for analysis. Up to 30 dB SNR improvement from zoom/ decimated layers.

Keysight Off-Line Analysis Compatibility
Native compatibility with Keysight 89600 VSA and associated post-processing toolchains.

Multi-Language API
- C/C++, C#, Python, LabVIEW, TestStand
- Full control of channel configuration, run-time. settings, triggers, metadata extraction, and headless automation.

Commercial, COTS, Non-ITAR / EAR99
Software-defined, customizable, and integration-ready.

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Multi-Channel RF Record Application

LIBERTY SYSTEM COMPONENTS

System Componets

- LIBERTY Real-Time Ingest / Processing Engine
- Keysight M5200A (PXIe), M8131A (AXIe) digitizers
- FPGA-based framing, tagging, alignment enforcement, metadata packetization
- Deterministic frequency, phase, amplitude, and time-skew alignment
- Integration with LIBERTY System Setup alignment profiles
- Multi-GB/s PCIe and ODI streaming

LIBERTY Recording & Metadata Store

- Continuous gapless logging (minutes → days)
- Automatic event tagging, bookmarks, alignment status indicators
- Multi-resolution full-rate and decimated layers
- Interleaved 16-bit I/Q or 16-bit Real storage
- Embedded metadata header documenting all acquisition parameters
- Keysight 89600 VSA compatible

High-Speed Recording Subsystem

- NVMe RAID arrays (4–128 TB)
- Continuous, snapshot, and triggered modes
- Removable NVMe sled capability

Quonset Microwave RF Front-Ends

- QM1003: 0.5–18 GHz
- QM1004-26-40: 26–40 GHz mmWave
- QM1040: adds 10 kHz–MHz HF/VHF

All maintain coherent multi-channel signal paths

REAL-TIME RECORDING PIPELINE

FPGA-Aligned Ingest & Validation

- Sample-accurate packet ordering
- CRC and sequence validation
- Per-sample timestamping
- Alignment-factor validity checks (amplitude/phase/frequency/skew)
- Frequency coherence enforcement
- Overload/clipping detection

Multi-Resolution Data Layers

- Full-rate RF/IF
- Optional decimation layers
- Offline IQ export & downconversion
- Interleaved 16-bit I/Q or Real sample structures

Capture Modes

All modes preserve multi-channel frequency and phase coherence, RF alignment, and channel dependency settings.

- Snapshot Mode
- Stream to SSD RAID via PXIe Backplane

MULTI-CHANNEL SYNCHRONIZATION & ALIGNMENT

The MC-RF-REC ensures deterministic multi-channel alignment across frequency, phase, amplitude, and time skew.

It works seamlessly with the LIBERTY System Setup Application, which performs automated RF channel alignment and provides alignment profiles used during live capture.

RF Alignment Specs

- Frequency coherence: sub-Hz drift
- Amplitude: < ±0.5 dB
- Phase: < ±0.5°
- Skew: < ±0.5 ps

Measured Performance

- 0.0057 dB amplitude
- 0.124° phase
- 1.6×10^{-13} s skew

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Multi-Channel RF Record Application

Supported Modes

- Independent, dependent, partially independent channels
- Input, output, mixed-path alignment
- Multi-frequency alignment
- Real-time alignment validity telemetry
- Auto-validation of alignment profiles

FREQUENCY RANGE & RF OPTIONS

Frequency Range	RF Module	Notes
10 kHz – 40 GHz	QM1040 + QM1004	Full-band continuous
26 – 40 GHz	QM1004-26-40	mmWave
0.5 – 18 GHz	QM1003 / QM1004	Microwave
IF Ranges	50–90 MHz, 50–550 MHz, 100–1100 MHz, 500–1500 MHz, 2–3 GHz	Selectable

SPECIFICATIONS

Multi-Channel RF Recorder

- Frequency Range: 10 kHz–40 GHz
- Instantaneous BW: 1 GHz (AXIe), 250–500 MHz (PXIe)
- Retune Time: <10 µs
- Zero-loss ingest
- Selectable channel count
- Independent / dependent / partially independent modes

Digitizers

- Sample Rates: 4.8 GS/s (PXIe), 16 GS/s (AXIe)
- Resolution: 10–12 bits
- Clock Jitter: <100 fs
- SFDR: 70–80 dB typical

Recording

- Throughput: 8–20+ GB/s
- Storage: 4–128 TB NVMe RAID
- Data Formats: Complex (I/Q), Real (I), Real (Q)
- Storage Format: Interleaved 16-bit I/Q or 16-bit Real
- Metadata Header: Embedded, self-describing
- Post-Processing: Compatible with Keysight 89600 VSA

SYSTEM CONFIGURATIONS

LIBERTY PXIe (Narrowband)

- 250–500 MHz IBW
- 4–20+ channels
- Portable, production test, chamber-integrated

LIBERTY AXIe (Wideband)

- 1 GHz/channel IBW
- Ideal for 4×4 and 8×8 ingest
- Multi-rack scalable
- Wideband SATCOM, 5G/6G, EW ingest
- Both platforms support selectable channel count and independent/dependent/partially independent operation.

CUSTOM INTEGRATED SOLUTIONS

LIBERTY can be delivered as:

- Stand-alone multi-channel recorder
- Chamber/OTA ingest subsystem
- Full 10 kHz–40 GHz ingest system
- Multi-rack ingest platforms for programs of record

TEVET provides full-stack integration, rack builds, ATE support, and deployment engineering.

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