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Addressing the Challenges of Multi-Channel, Phase-Aligned RF Systems

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Abstract

- Many electronic warfare systems utilise a multi-channel architecture, for tasks such as direction-finding in passive radar systems, or providing multipath redundancy in jamming-resistant communications.
- This paper discusses the challenges of implementing multi-channel, phase-aligned, RF systems, including:
  - Guaranteeing system synchronisation and trigger reliability
  - Achieving phase coherence and alignment
  - Performing in-line processing with real-time systems
  - Saving multi-channel RF data for analysis and playback
  - Optimising lab space and reducing power consumption

Challenge 1: Guaranteeing System Synchronization and Reliable Triggering

What does “Not Synchronized” Look Like?

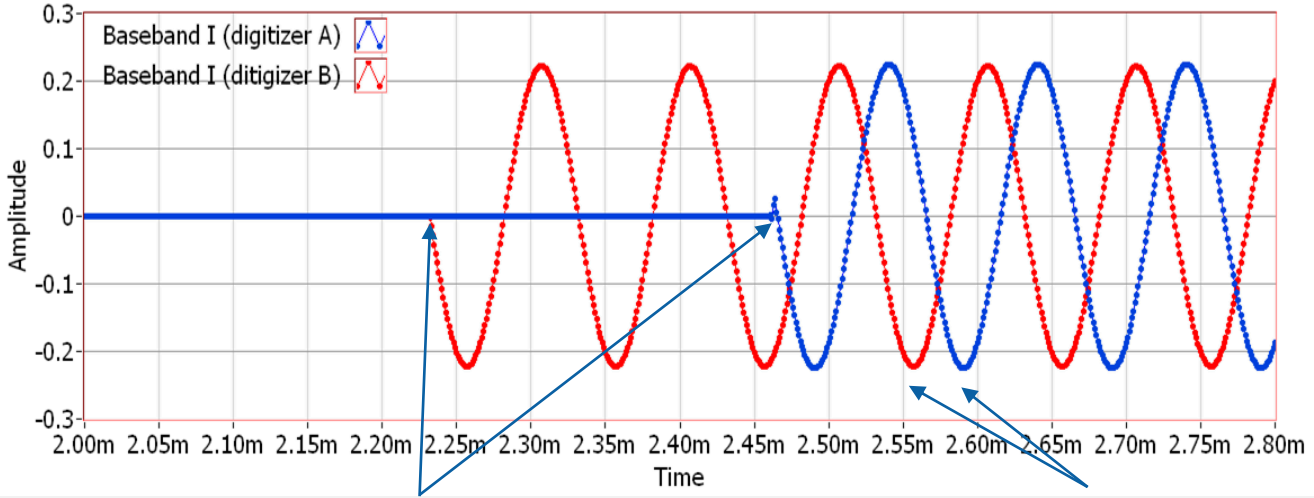
VSG generates a pulsed waveform

VSG

Center Frequency = f_1

VSA (CH 0) — Center Frequency = f_1 + offset

VSA (CH 1) — Center Frequency = f_1 + offset



Without a HW trigger, record acquisitions will begin at different times.

Over a short time interval, phase difference between ‘appears’ constant. However, over long time-intervals the phase of each channel will drift.

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Perfect Synchronization

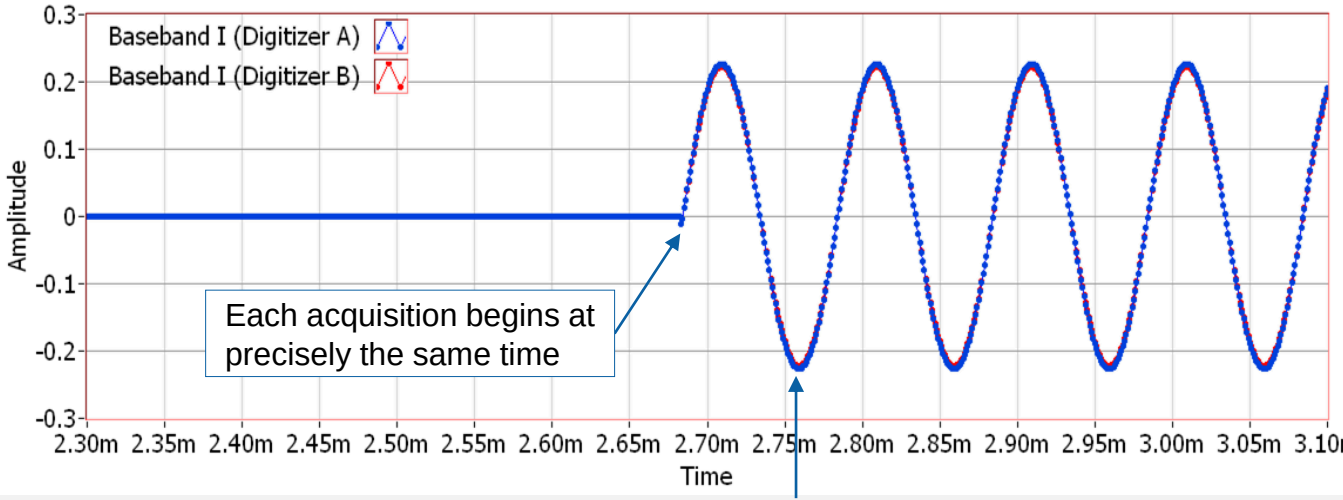
VSG generates a pulsed waveform

VSG

Center Frequency = f_1

VSA (CH 0) — Center Frequency = f_1 + offset

VSA (CH 1) — Center Frequency = f_1 + offset



Shared local oscillators and sample clocks result in precise phase synchronization

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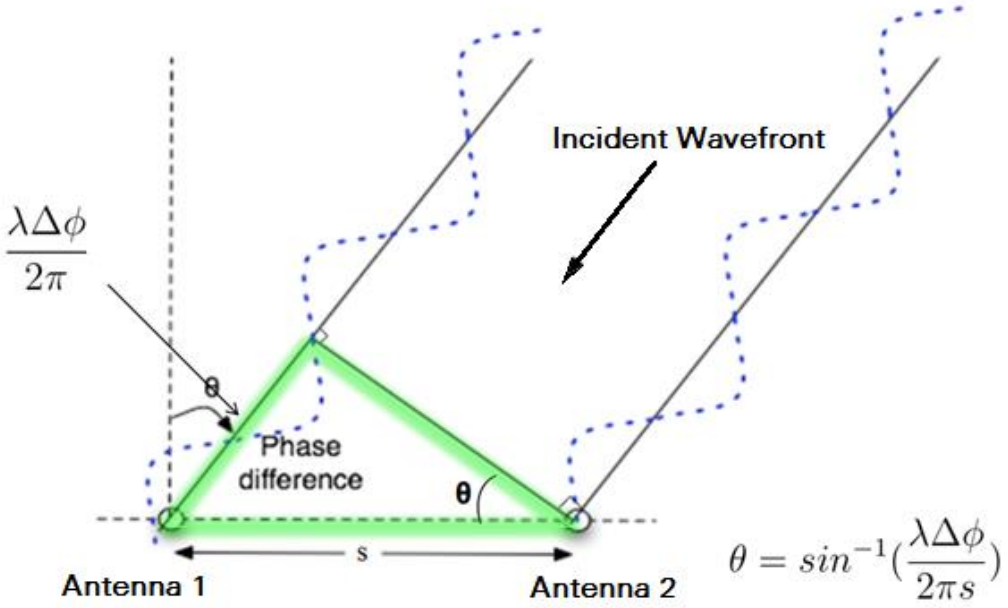

Challenge 2: Achieving Phase Coherence and Alignment

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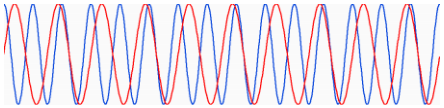
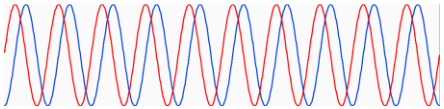
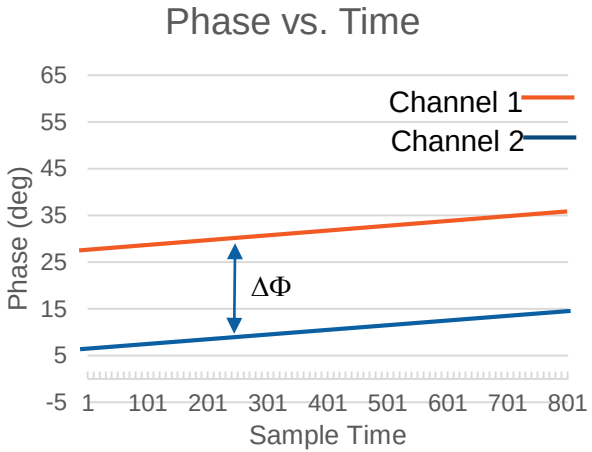
Levels of Frequency and Phase Coherence and Alignment

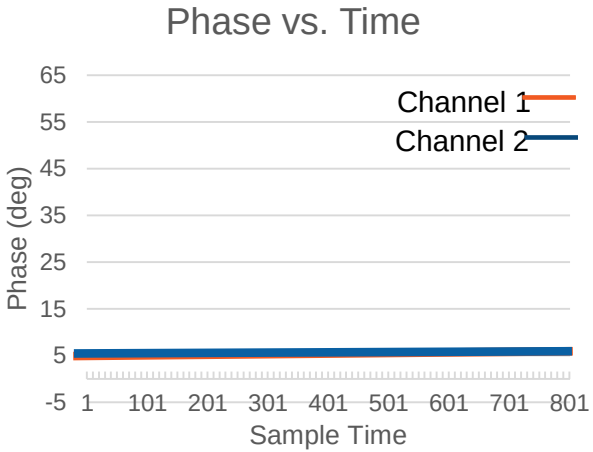


Different Frequencies



Same Frequency





FREQUENCY LOCK

PHASE COHERENCE

PHASE ALIGNMENT

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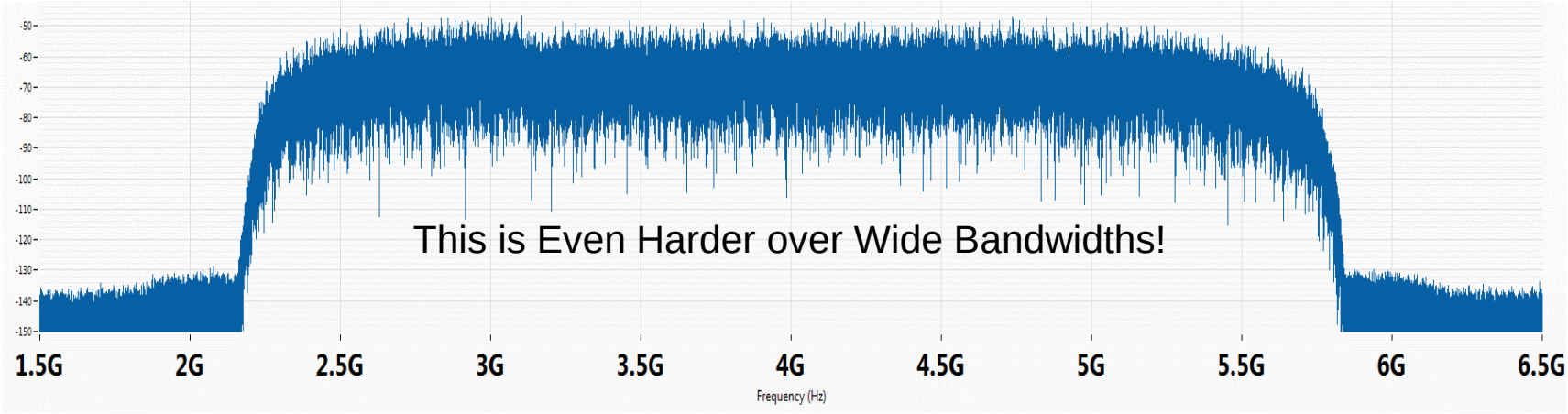
Levels of Frequency and Phase Coherence and Alignment



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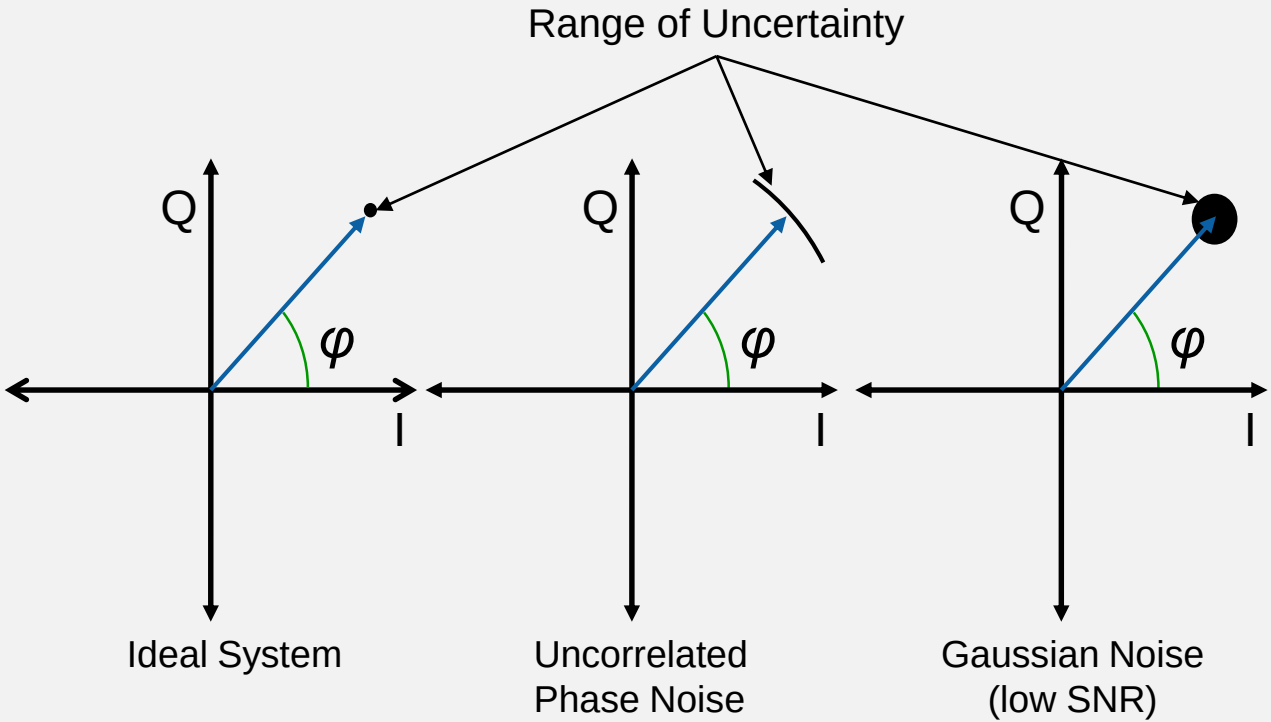
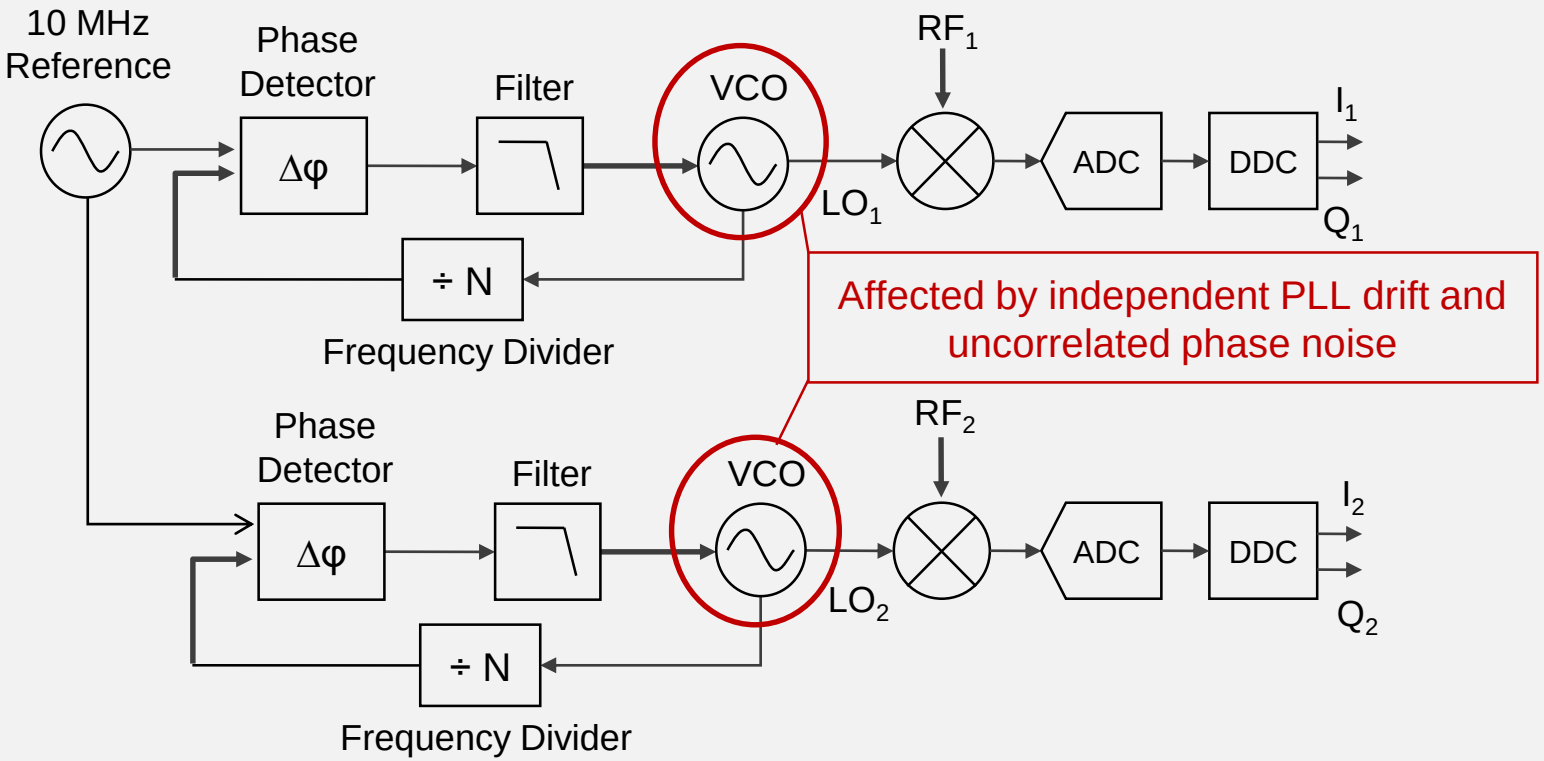
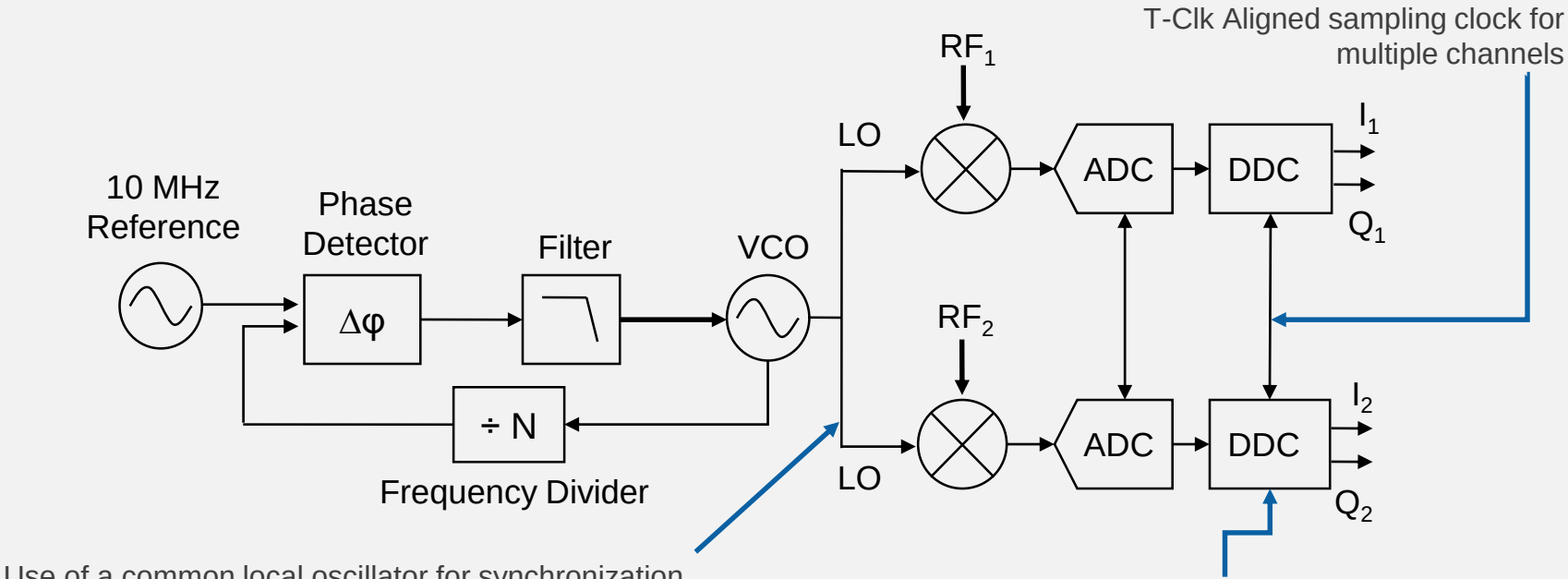
Cartesian Synchronization Representation



Traditional Synchronization Method

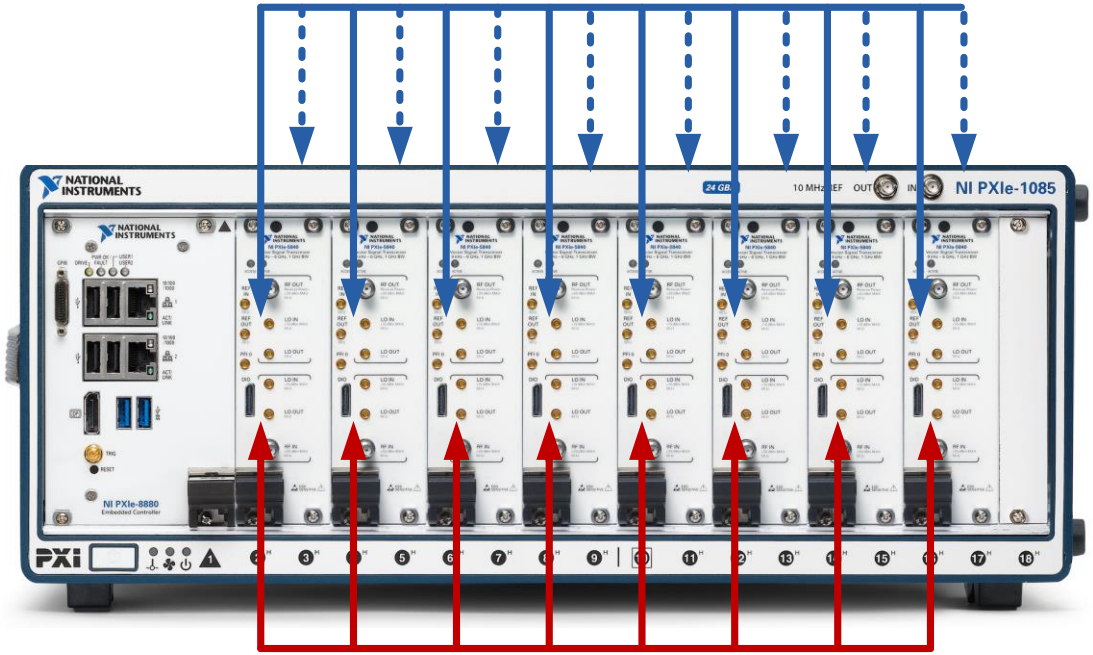


Achieve Synchronization Through Modularity



Minimize Trigger Delay and Guarantee Synchronization

Simplify Reference Clock and Trigger Distribution



8X8 MIMO System

Share Common Local Oscillator for Phase Alignment

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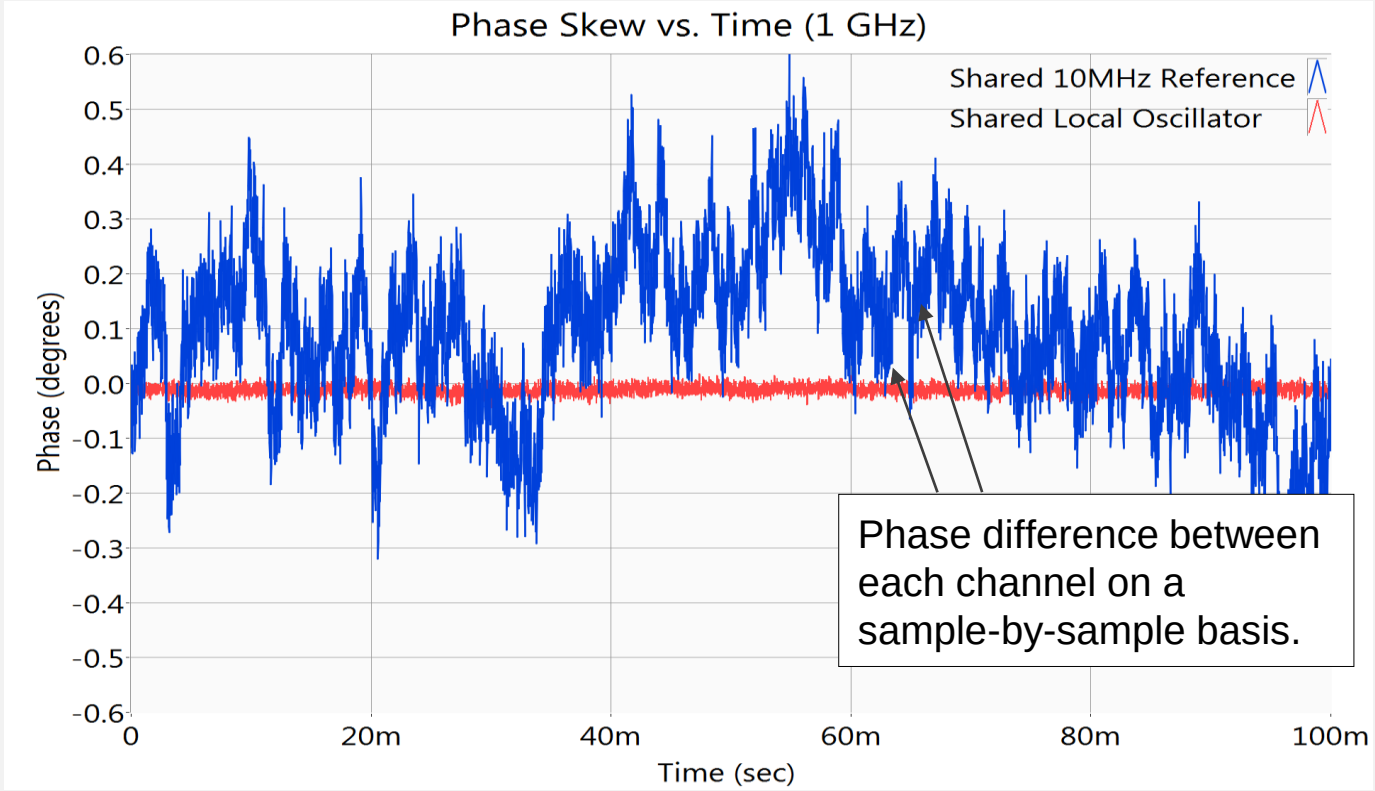
Shared Reference vs. Shared LO



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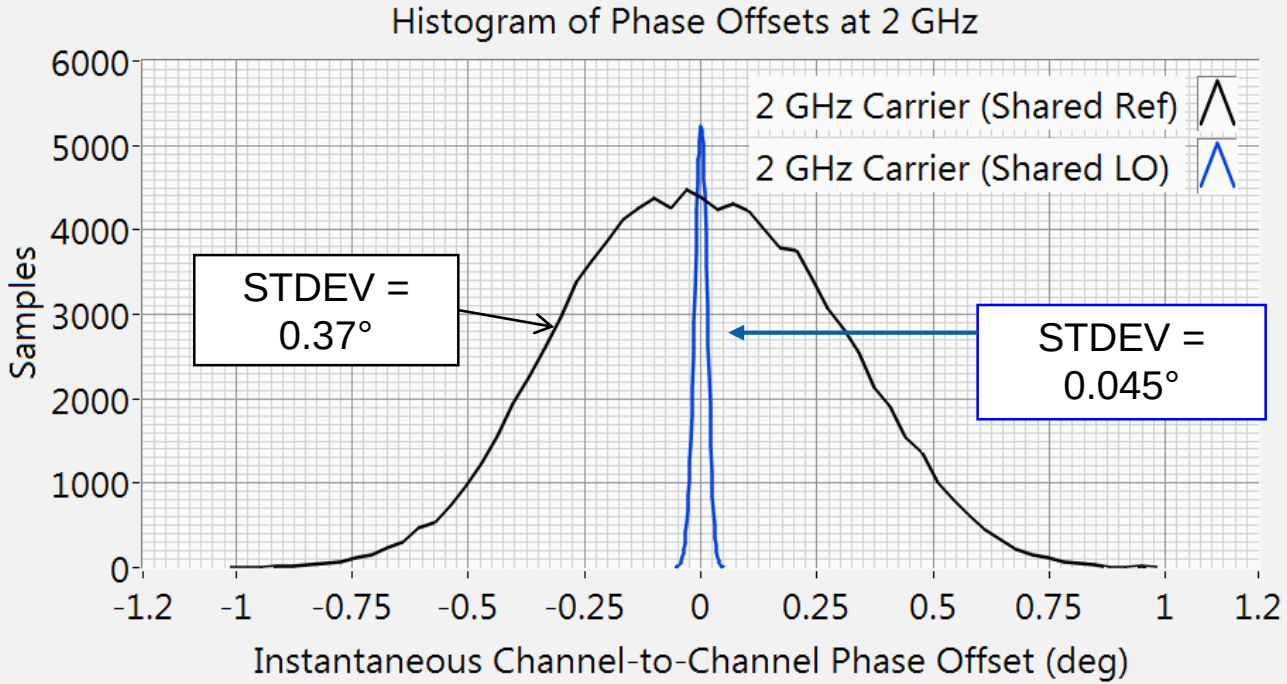
Channel-to-Channel Phase Accuracy



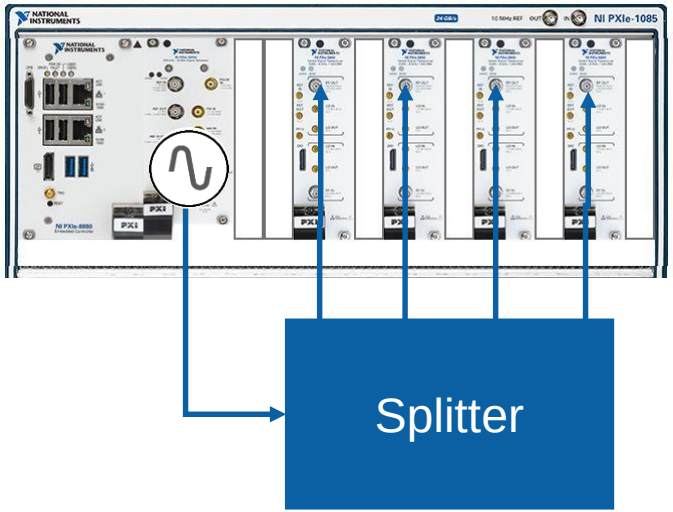
Delta Phase

2-Step System Calibration

Step 1: Calibrate RF In

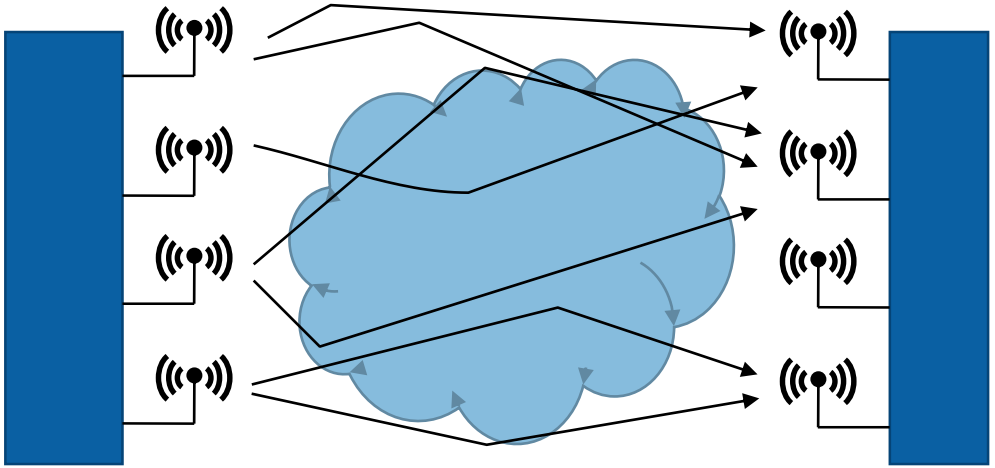
Multi-Channel Acquisition

CW Generator
or
VST Gen



Step 2: Calibrate RF Out

Use calibration loopback path to compute each channel's response and write to FPGA



Challenge 3: Create Real-Time Systems with In-line Processing of Samples

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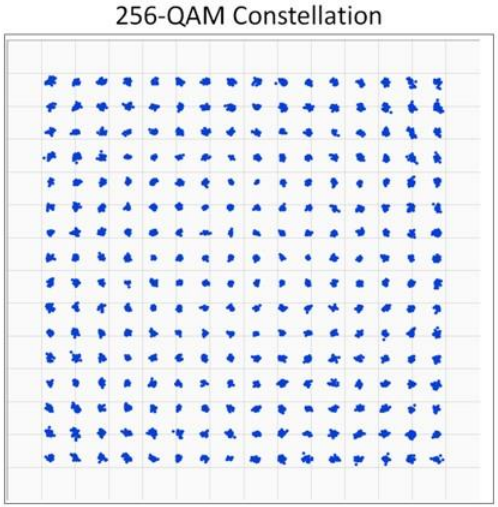
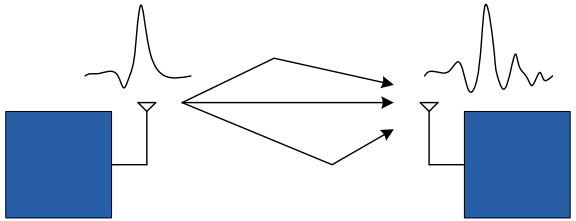
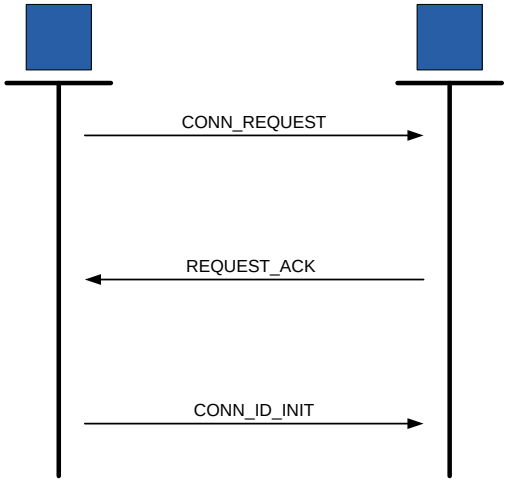
Create Real-Time, In-Line Signal Processing







PHY-LAYER MEASUREMENTS

CHANNEL SOUNDING

PROTOCOL SIGNALING

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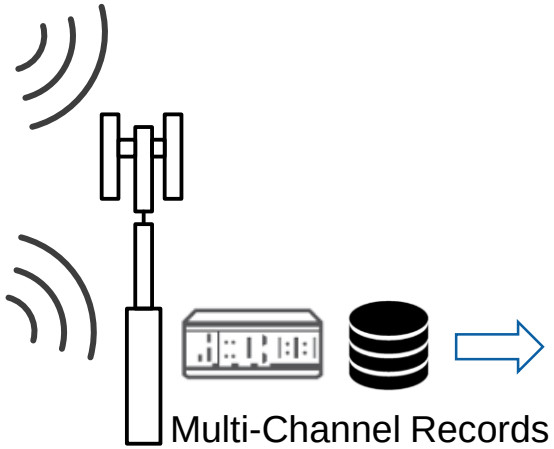
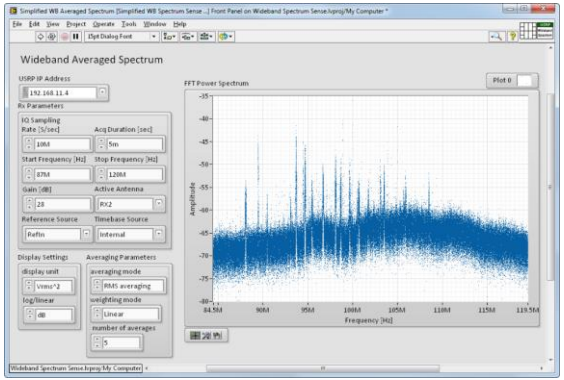
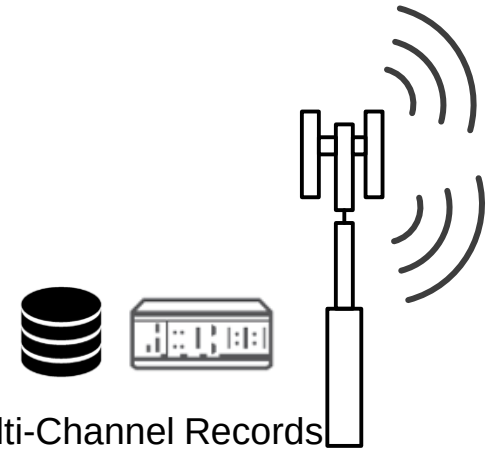
Challenge 4: Accelerate RF Research by Saving Multi-Channel RF Data for Later Analysis and Generation

Save Multi-Channel RF Data for Analysis and Generation



Multi-Channel Records





Multi-Channel Records

CAPTURE FIELD SIGNALS

ANALYZE IN THE LAB

MULTI-CHANNEL PLAYBACK

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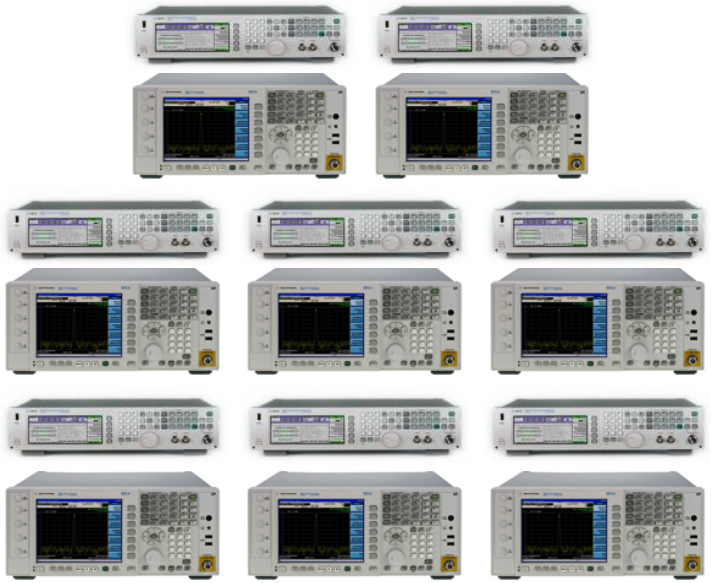

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Challenge 5:
Optimize Lab Space and Reduce Power Consumption

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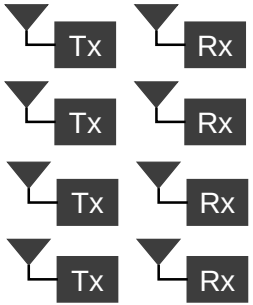
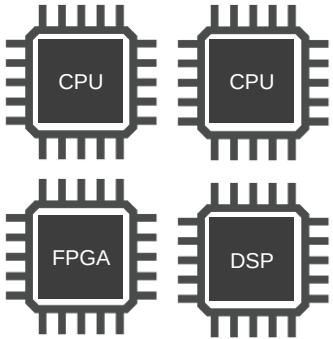
Common Elements of Multi-Channel RF Systems

Phase-coherent and Synchronized 1 to N Radio Front Ends



Data Bus

Multi-Processor Architecture



Data Bus

Reporting and Storage

Cloud

Local RAID

Software empowers faster development

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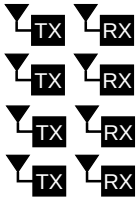
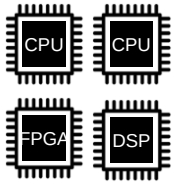
NI's Platform-Based Approach to Multi-Channel RF Systems



- Choose from a wide-range of RF hardware
- Use modularity to guarantee phase coherency
- Deploy on multiple platforms - from highly portable to high performance



- Speed up development with comprehensive signal processing libraries
- RFNoC and GNU radio toolchain support
- Integrate C, C++, .M, and VHDL code

Storage

- Take advantage of a large ecosystem of partners and developers
- Improve usability with native GUI and built-in remote access
- Guarantee synchronization and data storage

HARDWARE INTEGRATION | ALGORITHM DEVELOPMENT | SYSTEM COMPLETION

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NI's Platform-based Approach Offers Multiple Options for Synchronized, Phase-aligned, Multi-Channel RF Systems

USRP and FlexRIO

PXI

LOW-COST PROTOTYPING

QUICK DEVELOPMENT

INSTRUMENT-GRADE

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