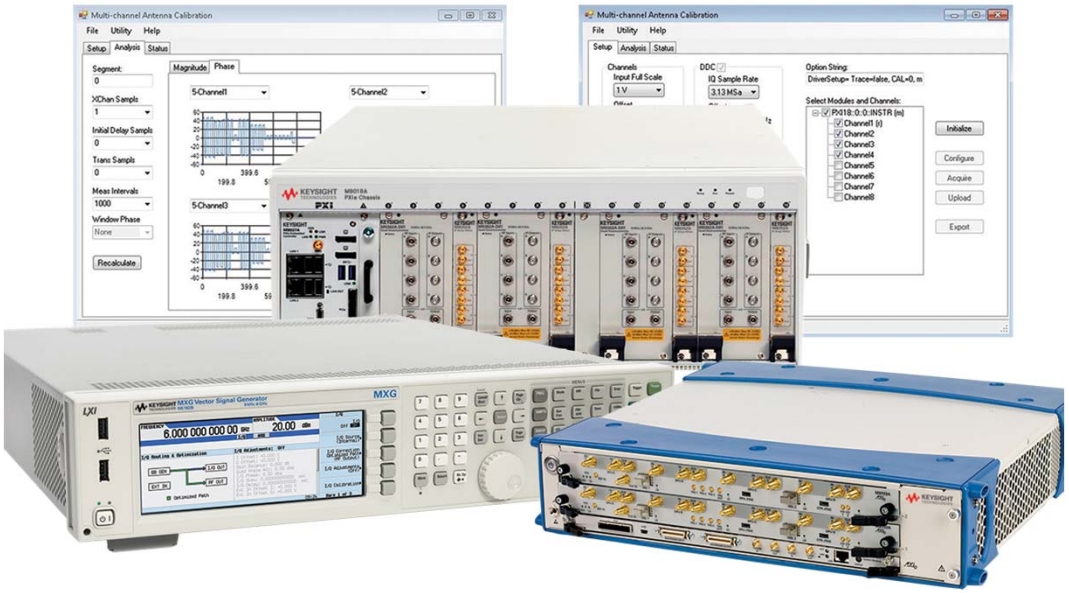
Multi-Channel Antenna Calibration Reference Solution

Nov 2014

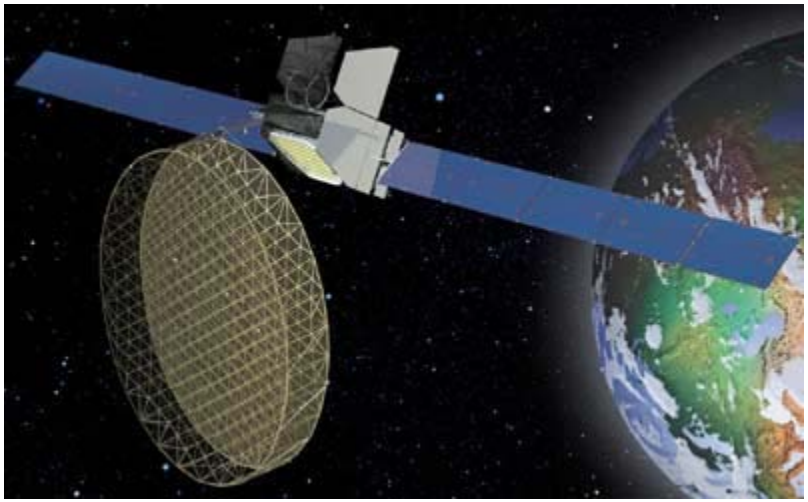


KEYSIGHT TECHNOLOGIES

Multi-Antenna Array Calibration Reference Solution
Agenda

- **Phased Array Applications Overview**
  - Antenna architectures and enabling technology
  - Benefits of modern phased array antennas
  - Test challenges of phased arrays
- **Configuring a Test System**
  - Application Block Diagram
  - System performance
  - Reference solution components
- **Finishing the solution**

Multi-Channel (Phased-array) Antenna

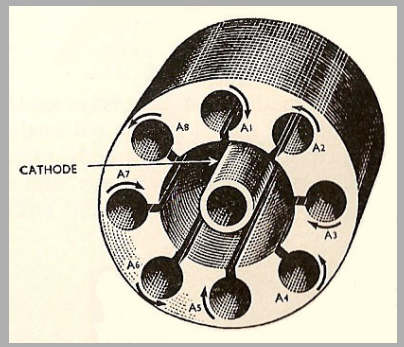
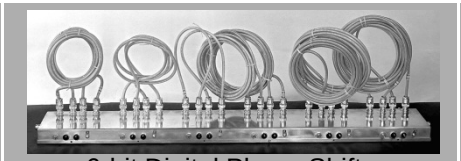
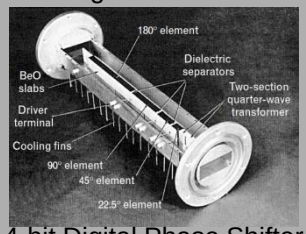
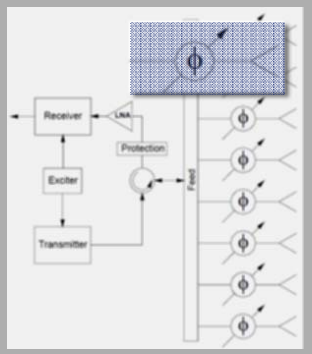
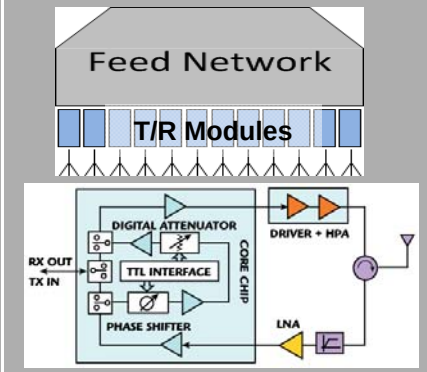


Multiple Spot Beams created from a single AESA antenna

AESA Installed on First US Air Force F15C – http://www.aviationnews.eu/

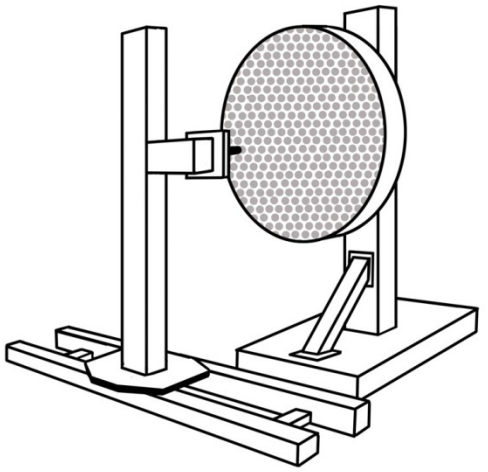
A multi-channel or phased-array antenna consists of multiple antennas or radiating elements that form a beam of specific shape or direction by manipulating the relative phase of each transmitted signal. Combining the elements of an array antenna with beamforming techniques enhances spatial selectivity and interference avoidance

Radar Antenna Architectures

Parabolic Dish Antenna	Mechanically Steered Array	Passive Electronically Scanned Array	Active Electronically Scanned Array
 Radar Dish Antenna	 Marconi Martello S-723	 AEGIS AN/SPY1D(V)	 APAR
 1940 - Cavity Magnetron	 6-bit Digital Phase Shifter  4-bit Digital Phase Shifter	 Integrated Phase Shifters	 T/R Module

Key Issues Faced by Antenna Array Test Engineers

- Calibrating large phase arrays requires phase synchronous sampling across all input channels, providing relative magnitude and phase measurements
- Array element counts are increasing, therefore calibration times are increasing
- Measurements require, high resolution sampling of IF signals and fast frequency-switching
- The need to test and calibrate multiple types of antenna require a flexible measurement system



Multi-Channel Antenna Calibration Reference Solution Benefits

Accelerate the calibration of large antenna arrays with precise cross-element phase and magnitude measurements while getting ready for the future with increased measurement bandwidth and system flexibility

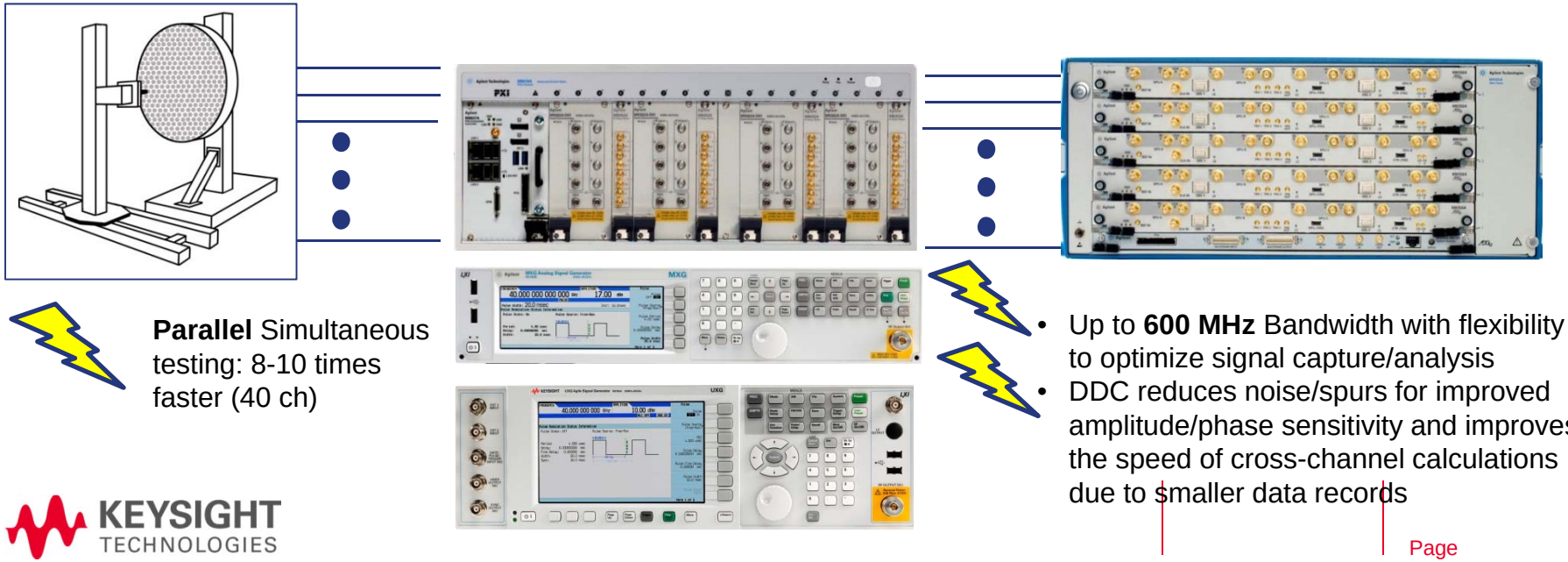
- Typical 8-10x improvement in measurement speed compared to a network analyzer solution (40 ch)
- Phase coherent sampling (<1 degree) across all input channels
- System is scalable to adopt different antennas or increase capability as needs change

Current Receiver Calibration Block Diagram

Sequential testing: switching 4 channels

15 MHz Bandwidth

Proposed Receiver Calibration Block Diagram



Parallel Simultaneous testing: 8-10 times faster (40 ch)

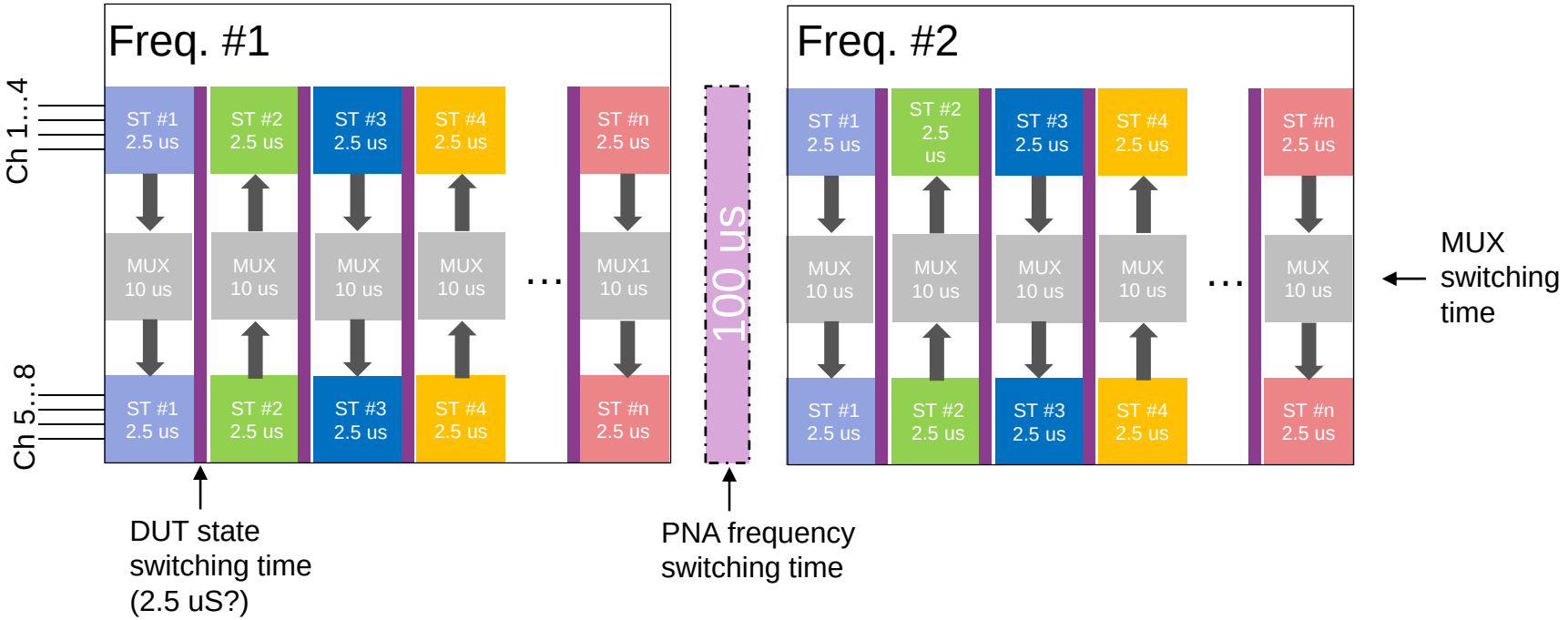
- Up to **600 MHz** Bandwidth with flexibility to optimize signal capture/analysis
- DDC reduces noise/spurs for improved amplitude/phase sensitivity and improves the speed of cross-channel calculations due to smaller data records

KEYSIGHT TECHNOLOGIES

Measurement Speed Example

Traditional PNA approach (1MHz BW)

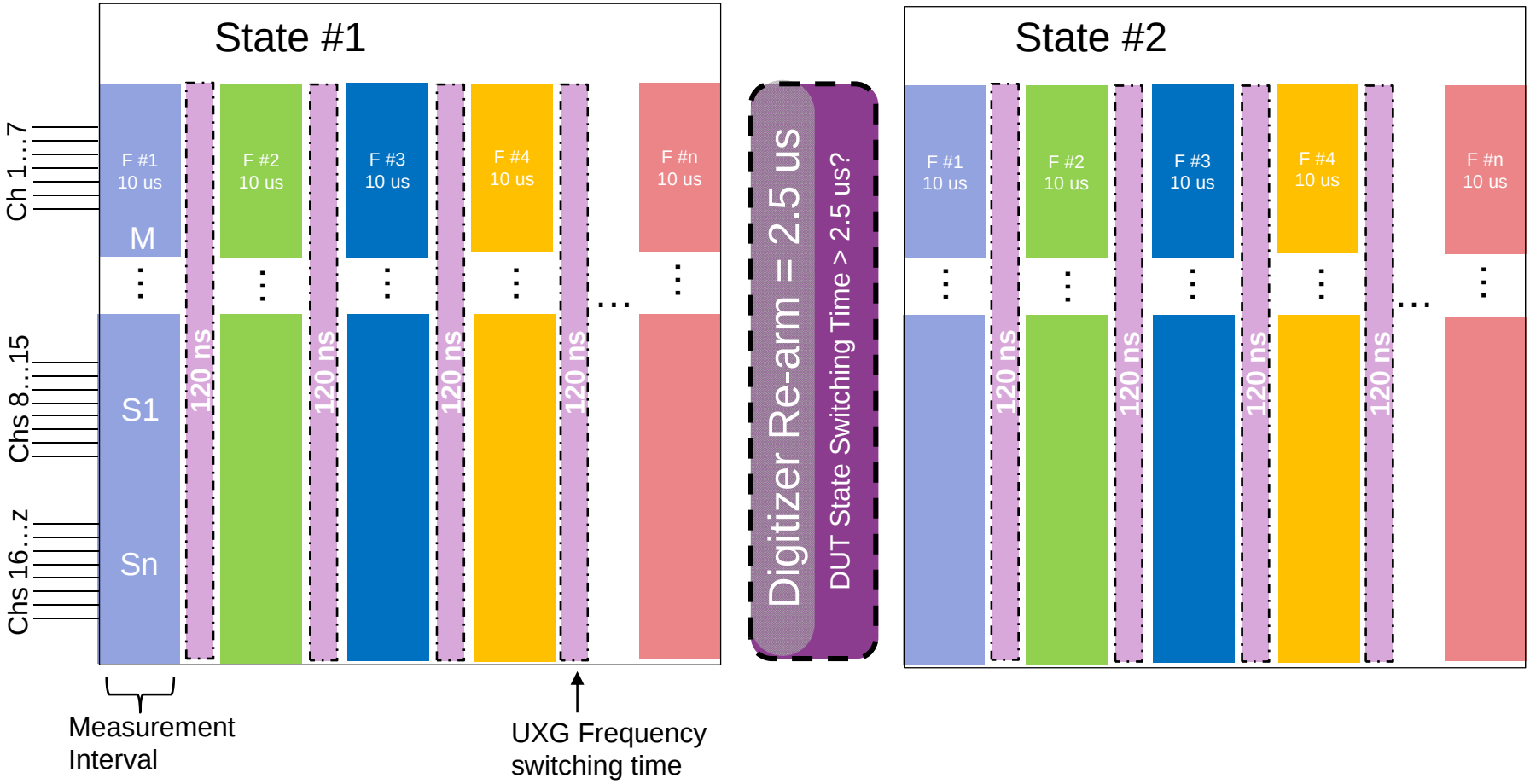
The idea is to put what is fast on the inside loop



- The PNA acquires 2.5us/pt to acquire a point on 4 channels (2.5us = PNA4CHtime)
- If the DUT switching time is > PNA frequency switching time, it may make sense to move state switching to the outside loop

Measurement Speed Example

Parallel approach (M9703A) with fast frequency switching (UXG)



- The M9703A acquires <u>all</u> channels (16 samples each) in 10 us with DDC and 1 MHz BW

Measurement Speed Comparison

Example:
- 1000 states (ST [=] phase/polarization), 2.5 μs DUT state switching time (SST)
- 30 frequencies (F)
- 1 MHz BW

Multi-Channel Antenna CalibrationReference Solution:

39 channels , 1000 states, 30 frequencies = **0.31 s**

$\left((Dwell\ + F_{sw}\,Time) * F\ Pts\ +\ Rearm|SST\right) * STs)$

((10us+120ns)*30+2.5us)*1000

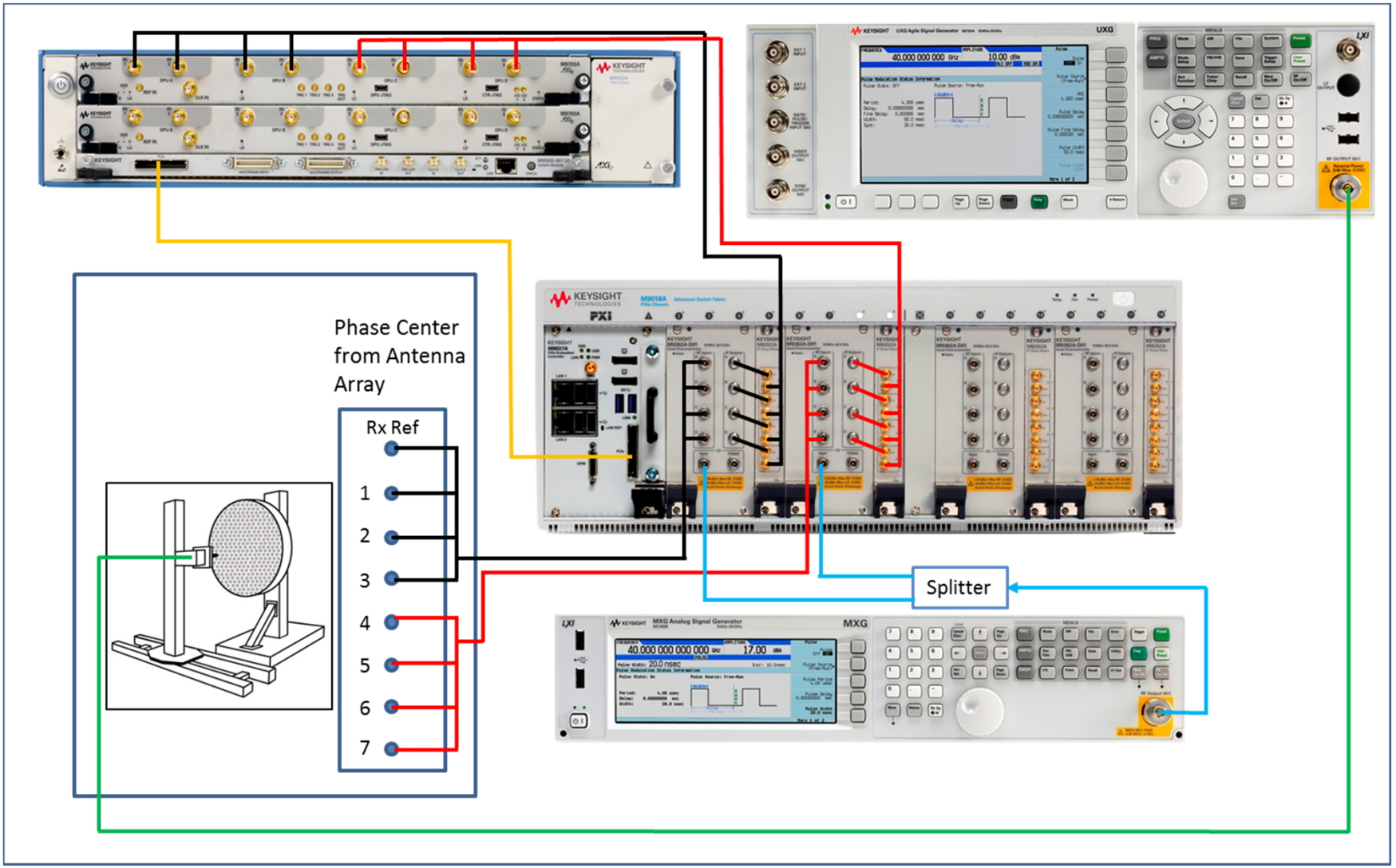
PNA:

40 channels, 1000 states, 30 frequencies = **3.53 s**

$\left((PNA4CHtime\ *\ \langle n\rangle 4chgroups\ +\ \langle n-1\rangle mux\ states\ +\ SST) * STs\ +\ F_{sw}\,Time\right) * F\ Pts$

((2.5us*10+90us+2.5us)*1000+100us)*30

Receiver Calibration Block Diagram



High-Performance, Scalable System

<1 degree phase coherence across all input channels

104 Channels

40 Channels

16 Channels

KEYSIGHT TECHNOLOGIES

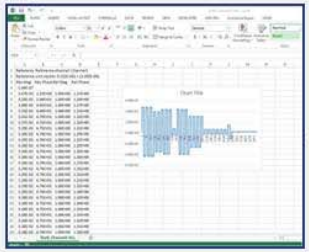
Typical System Performance

Typical Performance	
Number of Digitizer Channels	8 to 104 depending on configuration
Measurement Throughput	1M narrowband measurements per second (40 channels)
Phase Coherence	<1 degree across all channels
Non-decimated Bandwidth	625 MHz
Decimated Frequency Span (DDC)	300 MHz and $160/2^n$ MHz (n=0,1,2, … 18)
Measurement Frequency Range	DC – 40 GHz depending on down converters used (extended to 50GHz with additional calibration considerations)
Spurious Free Dynamic Range	60 dBc (typical) (non-decimated) 80 dBc (typical) (30MHz decimated)
Effective Number of Bits	8.8 (typical)
Acquisition Memory	Up to 1 GSa/ch

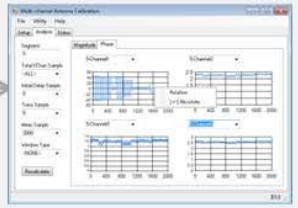
Reference Solution Components

Software

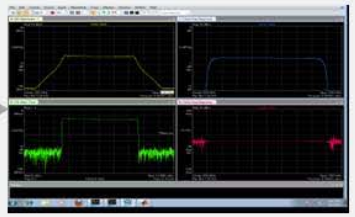
Open Text File Format
- Ch-to-Ch Amp and Phase measurements
- IQ Decimated Pairs
- Open file format for post processing



Automated Instrument Control
- Control to make Ch/Ch Phase and Magnitude Measurements



Ch-Ch Amplitude and Phase visualization



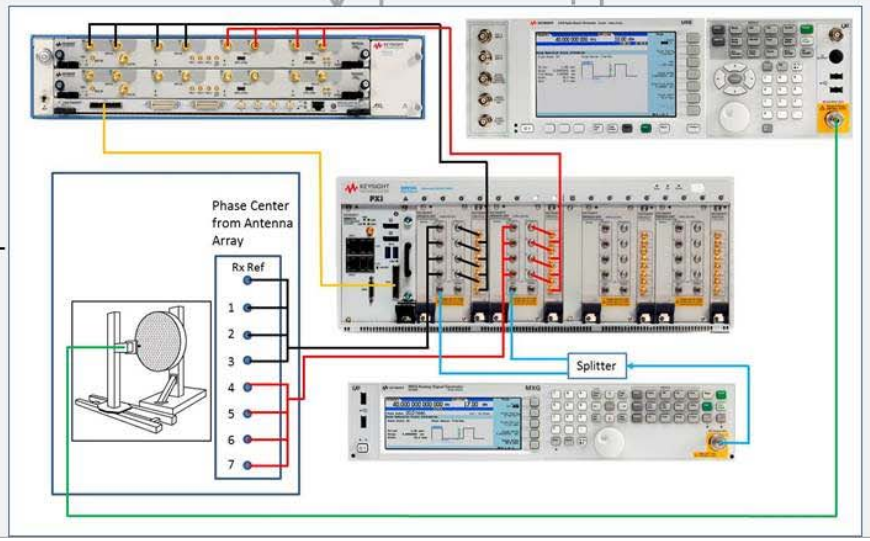
89601B VSA Software
- Visualization
- Cross channel wide-band measurements

Hardware

Baseband Hardware
- M9703A for digitizer and DDC

Front End Signal Conditioning
- M9362AD01 Quad Down-converters
- M9352A IF Signal Conditioning

Chassis and Controllers
- M9018A PXIe Chassis
- M9037A PXIe Controller
- M9505A AXIe Chassis

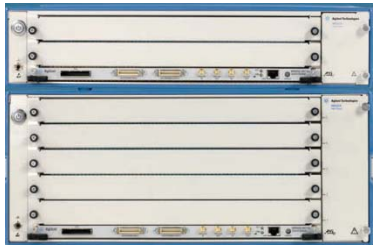


Local Oscillator
- N5183B MXG Analog Signal Generator
- N5193A UXG Agile Signal Generator

Reference Solution HW Components

M9703A AXIe High-Speed Digitizer
- 12 bit resolution
- 8 ch @ 1.6 GSa/s
- Up to 600 MHz Analysis BW
- Optional DDC

M9536A AXIe Embedded Controller
- Intel Xeon EP L5518 processor
- Up to 24 GB RAM
- 160 GD SSD
- USB (3), 10/100/1000 LAN (2), VGA (up to 1600x1200), RS-232



M9502A and M9505A AXIe Chassis
- 2 or 5 slots
- Embedded System Control Module
- 200W/slot

M9018A PXIe Chassis
- 18 Slots
- 867 Watts DC power
- Up to 42 w/slot cooling

M9362A-D01 PXIe Microwave Quad Downconverter
- 10 MHz to 26.5 GHz
- 4 coherent channel downconversion
- 1.5 GHz Analog BW

M9352A PXI Amplifier/Attenuator
- Four channels
- 10 MHz to 1 GHz Range
- 1Ghz Analog BW
- 31.5 dB IF attenuator (0.5 dB steps)

M9037A PXIe Embedded Controller
- Intel i7-4700EQ 2.4 GHz processor
- Up to 16 GB RAM and 240 GB SSD
- Front panel x8 PCIe interface can control an AXIe chassis

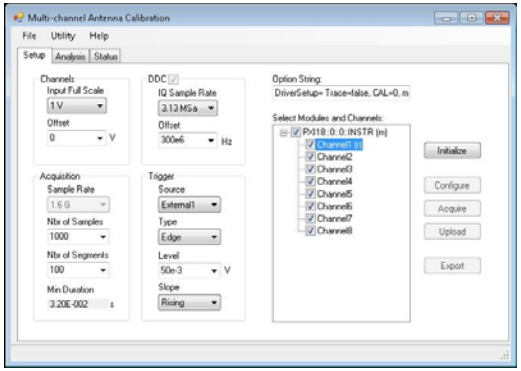
N5183B MXG Analog Signal Generator
- 13 – 40 GHz
- +20 dBm output power @ 20 GHz
- 600 us Frequency switching time (typ)

N5193A Agile Signal Generator
- 20 – 40 GHz
- +10 dBm output with optional attenuator
- Option 1 us and 2 ns switching time

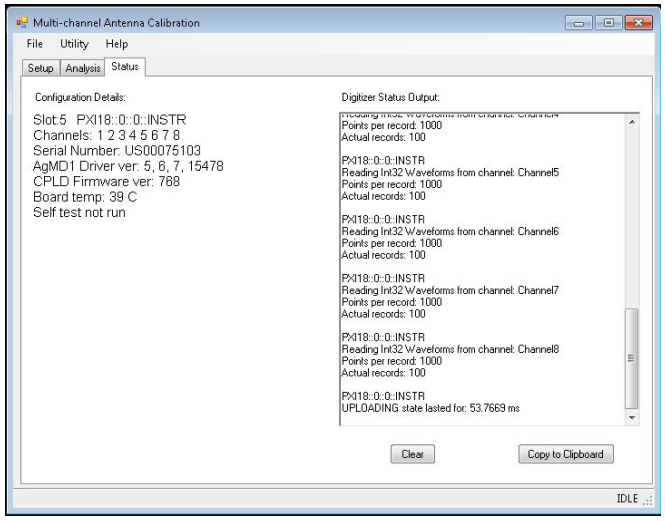
KEYSIGHT TECHNOLOGIES

Reference Solution Software (C#, .NET Class Lib)

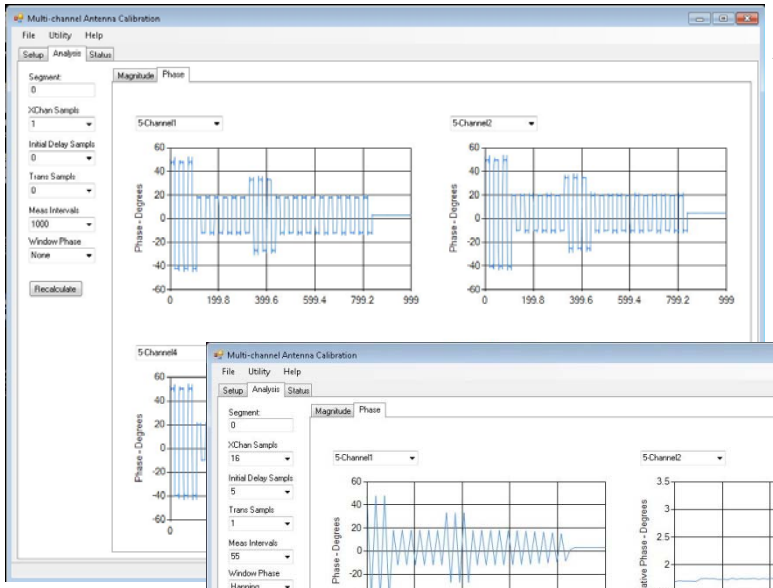
Setup and analysis



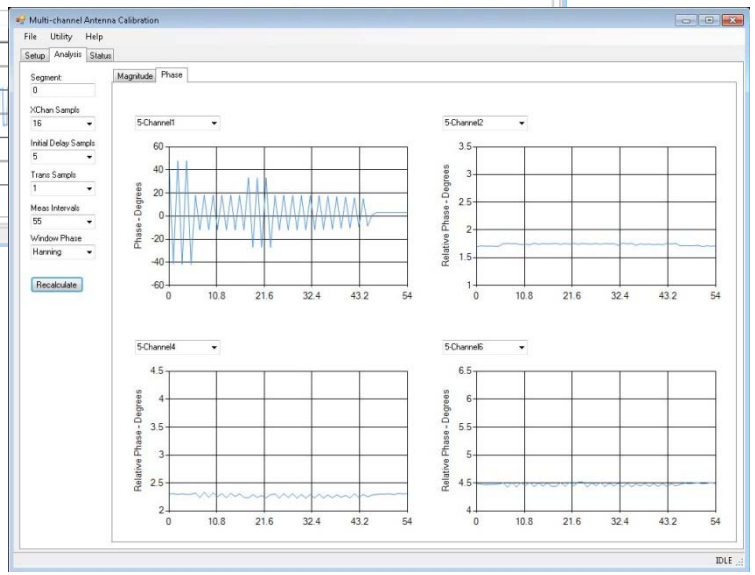
Test setup and control



Test status window



Absolute phase



Cross-channel (relative) phase after isolating measurement Intervals

KEYSIGHT TECHNOLOGIES

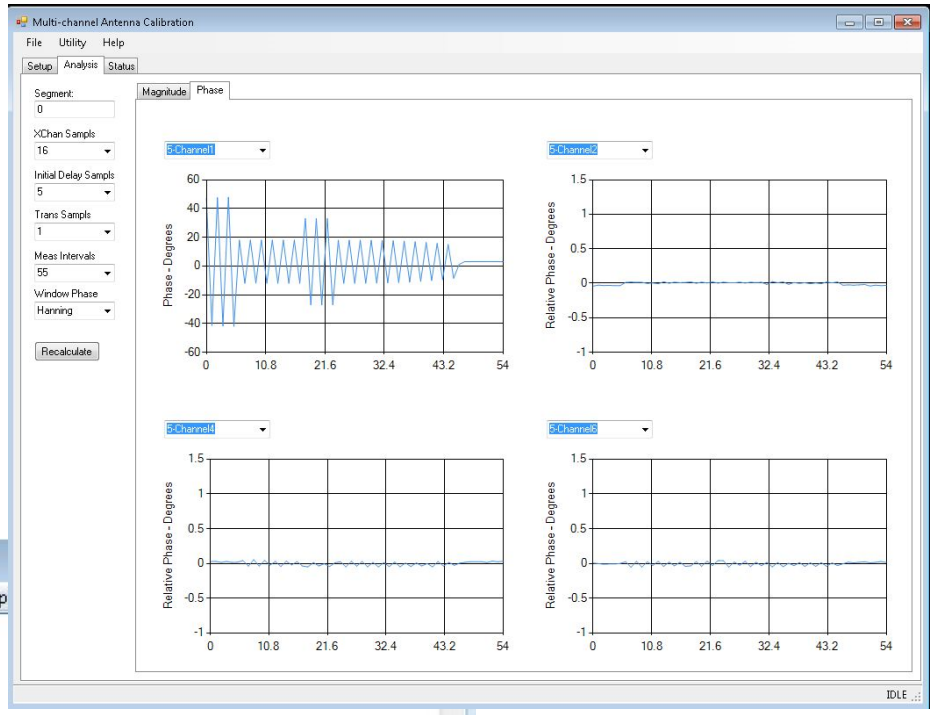
Reference Solution Software

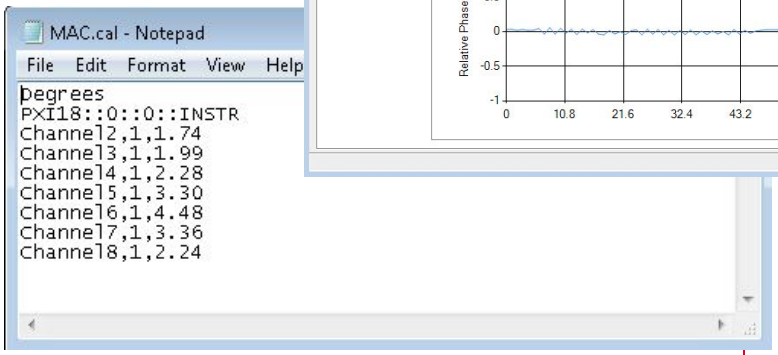
Utility and file functions

	A	B	C	D	E	F
1	Reference module: PXI18::0::0::INSTR Channel1					
2	Norm vector: 9.348E-001 - j3.551E-001					
3	Seg Time	Abs Mag	Abs Phase	Rel Mag	Rel Phase	
4	-5.19095E-007	0.0528263	47.6769	1.03616	2.24485	
5		0.050418	-42.0245	1.03599	2.2504	
6		0.0503985	47.5852	1.03582	2.24861	
7		0.0504084	-42.0243	1.03579	2.25268	
8		0.0504206	47.6036	1.03634	2.2506	
		0.0504163	-42.0475	1.03609	2.25725	
		0.0511135	39.2728	1.03581	2.31503	
		0.051592	-33.8411	1.03536	2.09638	
		0.0516181	39.2545	1.03604	2.31602	
		0.0516051	-33.8607	1.03594	2.09379	
		0.0512365	43.3699	1.03508	2.31262	
		0.0510157	-37.8169	1.03495	2.19123	
		0.0509767	43.3785	1.03442	2.31643	
		0.0510242	-37.8104	1.03515	2.18401	
		0.0510004	43.3958	1.03533	2.30676	
		0.0532578	-2.91498	1.03628	2.23483	
		0.0542131	8.46126	1.03572	2.1856	
		0.0541622	-2.94604	1.0358	2.24209	
		0.0527811	43.723	1.03449	2.32475	
		0.0509473	-38.1797	1.03459	2.17613	
		0.0509381	43.6987	1.03504	2.31893	

Exporting cross-channel measurements

Utilizing a calibration table

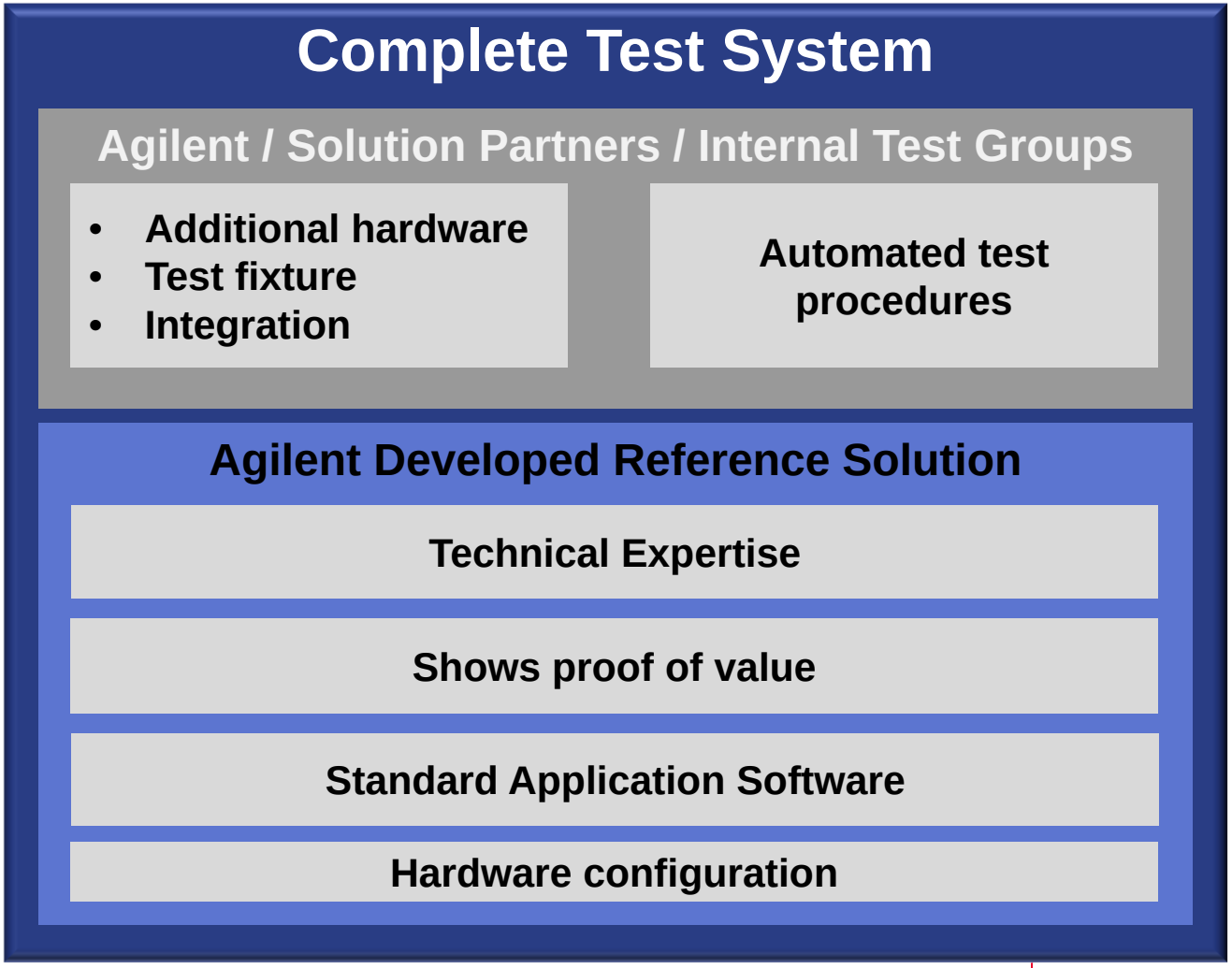




KEYSIGHT TECHNOLOGIES

Completing the Test System…

Reference Solution + **Enhancements** = **Complete Test System**



Agilent Solution Benefits

Accelerate the calibration of large antenna arrays with precise cross-element phase and magnitude measurements while getting ready for the future with increased measurement bandwidth and system flexibility

- **Speed:** Parallel Simultaneous Testing significantly reduces overall test time (up 10x improvement in measurement speed) and cost
- **Ultra stable and tracking coherent channels:** up to 104, high-resolution (12-bit) measurement channels which ensure stability across power, temperature, and frequency (less than 1 degree of phase difference across channels)
- **SW analysis tools:** Sample code for channel-to-channel amplitude/phase tracking in C# and LabVIEW to build upon
- **DDC option:** Ability to isolate the signal of interest and reduce the amount of integrated noise resulting in improved sensitivity for amplitude and phase measurements.
- **Flexible, up to 600 MHz bandwidth:** flexible bandwidth to make tradeoff between sensitivity and bandwidth.
- **Agilent solution partners:** allow you to get running quicker and easier.

Backup Slides

Resources

- Multi-Channel Antenna Calibration Reference Solution Brochure (5991-4537EN)
- Multi-Channel Antenna Calibration Reference Solution Configuration Guide (5991-4583EN)
- Achieve High Speed, Multichannel Data Acquisition with the M9703A AXIe DigitizerApplication Note (5991-1941EN)
- Increase Multi-Antenna Array Test Throughput with the M9703A AXIe DigitizerApplication Brief (5991-1351EN)
- Updated 2014 A/D Symposium Paper [Requires Login]
- Multi-Channel Antenna Calibration Reference Solution SW Demo [Requires Login]

MAC Reference Solution Value Proposition

Agilent Provides	Substantiation points
A Test Solution for Multi-Channel Antenna Calibration (RADAR)	• AXIe-based multi-channel IF digitizer with DDC • Down-conversion with choice of freq range and LO. • Choice of sources: fast-switching ARB + PSG for up-conversion or MXG • Evaluation software with GUI and built-in ch-ch phase-magnitude measurements
Covering frequency ranges through Ka band and selectable analysis BW	• PXI down-convertor options for 26 and 40 GHz for receive • 44 GHz PSG or 40 GHz MXG for transmit • 300 MHz (with DDC) - 600 MHz (without DDC) analysis BW
while providing reduced antenna calibration time	• All analysis channels measured in parallel • Typical 8-10x improvement in measurement speed (40 ch) • DDC optimizes the sample rate and amount of data
and improved beam-forming accuracy.	• Phase coherent sampling across all input channels • DDC reduces noise and spurs resulting in Improved amplitude/phase sensitivity
Easily gain confidence through simple evaluation,	• Includes test software application with GUI for quick demo/evaluation • Automated instrument control is included for fast phase and magnitude measurements
quickly integrate it in your test environment,	• Export file format for phase and magnitude measurements for post-processing in your test environment • Ability to add channel-channel magnitude/phase correction factors (at a fixed IF) to account for fixed offsets in cabling and fixturing • Test sw provided as a class library (for use in Microsoft Visual studio or built upon using LabVIEW) • Includes triggering capability for interfacing to the antenna scanner controller
and be ready for tomorrow with test system flexibility	• Start with narrow-band analysis today and take advantage of wideband capability in the future • System is scalable to adopt different antennas or increase capability as needs change

A/D Modular Reference Solutions

Multi-Channel Antenna Calibration

Reference Solution Deliverables:

1. Documentation: Individual module part numbers
2. Documentation: 8 channel block diagram
3. Documentation on how to setup the system
4. Typical performance results for the system
5. Sample channel to channel phase tracking test source code
6. Sample Self-Test Source code
7. Procedural calibration instructions
8. .Net DLL Driver to abstract hardware and make measurements
9. 2 days of AEO support provided with each delivery
10. Solution Hardware Configurator

Modern Active Electronically Scanned Phased Array (AESA)

AESA Installed on First US Air Force F15C – http://www.aviationnews.eu/

Key Benefits

- Fixed position antenna
- Ability to form multiple agile beams
- Fast scan rates with hard to predict, irregular scan patterns
- Independent transmit/receive modules per element
- Reduced power loss from integration of RF source on each T/R
- Graceful degradation – single source failure will not cripple system