安捷倫航太暨國防電子量測技術研討會

Book 2 of 3

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桃園 中科院龍園園區 W48館
國際會議廳
Topic 2

先進脈衝雷達測試技術
Testing modern pulsed radars using commercial instrumentation and software
Capture and analysis of pulsed Radar

Presented by:
Ryan Lu

Agenda

✓ Typical Radar measurements and measurement equipment
✓ Basic measurements and tools
✓ Modulation measurements and tools
✓ Arrayed radars measurements and tools
✓ Q&A
Radar Applications

- Surveillance
- Search
- Tracking
- Fire control
- Navigation
- Missile guidance
- Automotive collision avoidance
- Materials identification
- Atmospheric research
- Radar altimeters
- Proximity fuses
- Weather
- Ground mapping
- Ground penetrating
- Aircraft terrain avoidance
- Law enforcement
- Motion detectors

Radar Types

- CW
- Simple pulsed
- Pulse Doppler
- Pulse compression
- Height finding
- Multi-Mode
- Monopulse
- Phased array
- Synthetic aperture (SAR)
- Instrumentation
- Over the horizon
Simple Pulse Radar measurements

- **Basic measurements**
  - Pulse width
  - PRI (Pulse Repetition interval)
  - Pulse overshoot, undershoot, droop, rise and fall time
  - Pulse to pulse jitter
  - Pulse power
  - Pulse amplitude
  - Spur search
  - Various carrier measurements
  - Transition measures – mode changes
Tools for measuring pulsed radar waveforms

• General Purpose:
  – Power meter (peak, average)
  – Counter
  – Spectrum Analyzer
  – Oscilloscope

• Specialty:
  – Pulse Analyzer System (monitoring, production)
  – Noise Figure Analyzer (component measurements)
  – Vector Network Analyzer (component, antenna)

• Software:
  – Vector Signal Analysis (VSA), Pulse Analysis, Pulse building software, etc.

Measurement Tool Comparison

**Spectrum Analyzer**
- Wide Frequency Range
- Good Dynamic Range
- Limited Instantaneous Bandwidth
- Limited Time Capture Length
- Difficult to Measure Pulse Parameters
- Traditionally doesn’t capture phase information

**Oscilloscope**
- Wide Bandwidth
- Flexible
- Limited Time Capture Length vs. Pulse Analyzer
- Greater Overhead (Samples)
- Limited Frequency Range (No internal down-converter)

**Pulse Analyzer**
- Very Long Time Captures
- Very Precise Pulse Time Information
- Amplitude Measurements Optional (Digitizer)
Pulse Power Measurement – Power Meter

• Peak power meter provides graphical view detailing pulse characteristics
• Rise time, fall time, and pulse width are shown below the trace
• Power meters are typically the most accurate tool for power measurements

Spectrum/Signal Analyzer Time Domain Measurements

• Spectrum analyzers can be used like an oscilloscope to measure RF pulse time domain characteristics—in zero-span mode
• Trigger level and trigger delay controls allow viewing the rising edge of the pulse
• Peak search markers can be used to measure peak power.
Signal Analyzer Pulse Width Measurements

- Increase trace points to suitable range
- Ensure RBW is wide enough
- Use delta markers at –6 dB point on pulse to measure width.

SA Peak Power Measurements and RBW

- Effects of RBW on pulse shape
- Three pulse widths shown: 500 ns, 200 ns, and 100 ns
- To accurately measure peak power, the analyzer bandwidth must be wide enough to settle within the pulse width.

\[
\text{Settling Time} \propto \frac{1}{RBW} \quad \text{Rise Time} \propto \frac{0.7}{RBW}
\]
SA Measurement of PRT

- Adjust display so that at least two pulses are displayed
- Use delta markers to display the pulse repetition time.

Other common SA pulse measurements

- Line spectrum
- Pulse spectrum
- Pulse power
- Spur search
Using Oscilloscopes for Pulse Measurements

Oscilloscope Pulse Measurements (Direct Capture)

Captured with Oscilloscope. Analyzed with built in Math (Low Pass Filter) and Jitter analysis (Trend and Statistics)
Scope Pulse Measurements (Direct Capture)

Direct capture maintains the modulation details

Use of segmented memory

Captured with Oscilloscope, 1GB of memory and 16 thousand 64k byte segments. Last burst 16 seconds after the first

150km unambiguous range – 1ms PRI

Sub picosecond resolution on segment timing
Scope PRI (Period) vs. Time

- Measurement trending identifies RADAR mode changes vs. time
- PW vs. Time can also be displayed
- Triggering on change in PRI
- Part of oscilloscope "Jitter" measurement package

Scope Pulse Envelope vs. Time

Captured with Oscilloscope. Analyzed with built in Jitter analysis

Pulse Width Trend
Radar Pulse Analysis SW (SA and Scope)

Captured with Oscilloscope and Pulse Measurement Software

Oscilloscope Pulse Measurements (Frequency)

Captured with Oscilloscope. Analyzed with built in FFT

Scope based FFT
Oscilloscope Pulse Measurements (Frequency)

Captured with Oscilloscope. Analyzed with built in FFT (Magnitude and Phase) and Jitter analysis

Beyond FFTs, including Measurement Trends

Sample Radar measurements

- **Modulation**
  - Modulation type (verify proper modulation)
  - Modulation quality (e.g. distortions and nonlinearities)
  - Phase vs. time or frequency
  - Time and frequency selective measurements
  - I/Q modulator gain/phase imbalance
  - Demodulation analysis for pulse compression applications
What is VSA?

• Vector Signal Analyzer (VSA)
  – Vector detect an input signal (measure magnitude and phase of the input signal)
• Measurement receiver with system architecture that is analogous to a digital communications system
  – In some sense the ultimate Software Defined Radio (SDR)
• Similar to FFT analyzer, but VSAs have powerful vector/modulation-domain analysis for complex RADAR
  – Time data Real I(t) & Imaginary Q (t)
  – Phase verses Time or Frequency
  – Time and frequency selective measurements
  – Demodulates Carrier and extracts AM, PM, & FM
  – User definable digital demodulator
  – I-Q Modulator Gain/Phase Imbalance
Signal Changes or Modifications (Polar Graph)

Magnitude Change

Phase Change

Frequency Change

Both Change

VSA Software used in digital, IF and RF domains

DUT

DSP

Digital (SSI)

BB (I-Q)

IF/RF

Logic Analyzer

Oscilloscope

Signal Analyzer
Vector Signal Analysis (Beyond Pulse Shape)

Pulse measurements help characterize a radar system, Vector Signal Analysis helps detect the modulation (signal changes)
Example of Chirp Demodulation

- VSA software used to demodulate a linear FM chirped radar signal
- Displays of the signal spectrum, pulse envelope, phase verses time, and frequency verses time are shown.

Example of 7-Level Barker Code

- 89601A VSA used to analyze a 7-bit barker coded pulse
- $\pm180^\circ$ phase modulation in pattern of + + + - - + - applied to pulse
- Displays of pulse spectrum, IQ, pulse envelope, and phase verses time are shown.
Spectrogram of Frequency Hopper

- Spectrogram shows frequency on the X-axis, time on the Y-axis, and amplitude as color.
- The spectrogram is an excellent tool for analyzing events that are rapidly changing in time.

Frequency vs. Time

Current point in time
Down-conversion and analysis of pulsed RADAR

PXA Signal Analyzer:
140MHz Bandwidth, carrier frequencies to 26.5 GHz.
Programmable IF output to 600MHz Bandwidth
One Channel

PSA

Wide Band VSA 300 MHz wide, carrier frequencies to 50 GHz, one channel using a Spec An (IF out) and Oscilloscope

Ultra Wideband VSA 1.5 GHz wide, carrier frequencies to 50 GHz, Four channels using Oscilloscope and 4 channel coherent downconverter
Sample Radar measurements – Arrayed radars

- **Arrayed radars**
  - Previous measurements across multiple phased-array channels
  - Channel offsets (phase offsets)
  - Channel to channel repeatability
  - Pulse to pulse amplitude and phase repeatability
- Generally use a scope for these measurements (may need a downconverter)

Phased Array Measurements

- Multiple phase correlated measurement channels necessary
- Timing between multiple emitters critical for steering
- 100s of correlated channels possible with cross triggering.
Sources of Phase Error

Phased array steering errors can result from several factors:

- Phase shifter calibration uncertainty
- Transmission delay uncertainties
- Power amplifier nonlinearities
- Power amp AM to PM distortion
- Power amp heating during the pulse
- Amplifier load pulling
- Sensitivity to power supply fluctuations

Possible Amplifier Measurements

- Pulse to pulse magnitude/phase stability
- Relative magnitude/phase relationship between channels
- Absolute magnitude/phase relationships between channels

Over time, to observe amplitude and delay instability in the amplifiers (due to thermal drift, active compensation, etc.)

As a function of signal power. Use cross-channel measurements (e.g. frequency response) to detect delay changes caused by variations in the output power of one amp relative to another.
Multi-Channel VSA Measurements

Multi-Channel VSA measurements provide more than twice the information of single-channel measurements

- With two spectrum analyzers you can only measure two spectrums
- With two coherent channels you can measure two individual spectrums, but you can also measure:
  - The cross-channel spectrum
  - Channel-to-channel frequency response
  - Channel-to-channel impulse response
  - Channel-to-channel correlation function
  - Channel-to-channel amplitude and phase repeatability

The Agilent VSA software allows up to 4 simultaneous measurement channels

Two-Channel Measurement on Radar TR Module With Actual Pulse Drive Conditions
A Two-Channel measurement Made With an 8 ns Pulse

Phase response after cal, but prior to amplitude change
Amplifier Drive Level Increased 10 dB. Notice 15 Degrees of Phase Pulling

VSA software on Agilent Infiniium Oscilloscopes

- Provides Wideband and Ultra Wideband Analysis for RF R&D Engineers.
  - 25ms, 8GHz wide recordings
  - 4 Correlated Analog Channels
  - 50 Ohm or Probed
  - BBIQ, IF, RF Signals
  - Carrier frequencies up to 13GHz; 50GHz with Agilent down converters
- 89601A VSA SW
  - 100s of Modulation Standards
    - Flexible Vector Modulation
    - UWB
    - MIMO
  - MSO, correlated digital channels
VSA software on Agilent Signal Analyzers

Provides Wideband Analysis for RF R&D Engineers.
– Up to 140MHz bandwidth
– BBIQ, IF, RF Signals
– Carrier frequencies up to 50GHz
– 89601A VSA SW
– 100s of Modulation Standards
– Flexible Vector Modulation

Agilent’s Family of Oscilloscopes

New 9000 series: large screen, optional digital channels, 1GHz, 2.5 GHz and 4 GHz Models
8 channel scope now available: DSO91308A

Q&A
Agilent PSA Series
High-Performance Spectrum Analyzers

Now with the industry’s first 80 MHz analysis bandwidth for signals up to 50 GHz
The brainpower and the will are already yours; the next step is selecting precisely the right tools to reach the market first.

The Agilent PSA Series offers high-performance spectrum analysis up to 50 GHz and beyond with powerful one-button measurements, a versatile feature set, and a leading-edge combination of flexibility, speed, accuracy, and dynamic range. From millimeter wave and phase noise measurements to spur searches and modulation analysis, the PSA Series offers unique and comprehensive high-performance solutions to R&D and manufacturing engineers in cellular and emerging wireless communications, aerospace, and defense.

Performance Exceeding Expectations

Dynamic range
Fine-tune measurements with the industry’s most usable dynamic range.

Accuracy
Design with confidence using industry’s highest accuracy.

Flexibility
Take control of measurement setups through advanced flexibility.

Analysis bandwidth
Maximize your signal analysis capabilities with up to 80 MHz of analysis bandwidth built-in (14-bit digitizer resolution); and up to 300 MHz of analysis bandwidth by using an oscilloscope as a digitizer.

PSA Series frequency range summary

<table>
<thead>
<tr>
<th>Model</th>
<th>Resolution</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>E4432A</td>
<td>3 Hz</td>
<td>6.7 GHz</td>
</tr>
<tr>
<td>E4445A</td>
<td>3 Hz</td>
<td>13.2 GHz</td>
</tr>
<tr>
<td>E4440A</td>
<td>3 Hz</td>
<td>26.5 GHz</td>
</tr>
<tr>
<td>E4447A</td>
<td>3 Hz</td>
<td>42.98 GHz</td>
</tr>
<tr>
<td>E4446A</td>
<td>3 Hz</td>
<td>44 GHz</td>
</tr>
<tr>
<td>E4448A</td>
<td>3 Hz</td>
<td>50 GHz</td>
</tr>
</tbody>
</table>

The new Agilent N9030A PXA signal analyzer (currently available up to 26.5 GHz) is built on the heritage of the venerable PSA legacy with the latest technologies. Customers who seek performance and usability beyond the PSA may consider the PXA to maximize their signal insights. PSA owners who seek a migration solution should take advantage of the PXA’s “Form/Fit/Function” compatibility with the PSA to mitigate migration risks.
Coherent Multi-Channel & Diversity Systems - Phase Coherency & Stability Between Multiple Signal Sources
Coherent Multi-Channel & Diversity Systems
Phase Coherency and Stability Between Multiple Signal Sources

Presented by:
John Hansen
Senior Applications Engineer

Agenda

Coherent Multi-Channel & Diversity Systems
Phase Coherency Between Multiple Signal Sources

- Definition & problem statement
- Applications
- Test challenges
- Test system configuration and performance considerations
- Solutions
  - Phase stable solutions
  - Phase coherent solutions
- Multi-channel receiver measurements
Agenda

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Coherent signals constructively combine

Transmitter

Direct Ray

Reflected Ray

180° Phase Shift

Receiver

Wave Front

Delay

Beam Forming Network (BFN)

Multi-path

Beam Forming
Coherent sources challenges

- Non-Coherent Signals
- Coherent Signal Generation
- Controllable Phase Relation
- Configurable Modulations
- Trigger-able Pulses

Definition of coherence

Coherence:

\[ \rho_{XY} = \frac{E\{ (X - \mu_X)(Y - \mu_Y) \}}{\sigma_X \sigma_Y} = \frac{\sigma_{XY}}{\sigma_X \sigma_Y} \]

Where:
- \( \rho \) = coherence
- \( E \) = expected value operator
- \( \mu \) = average value
- \( \sigma \) = std deviation
- \( X \) = signal X
- \( Y \) = signal Y

\( \rho = 1 \) fully coherent
\( \rho < 1 \) but \( \rho > 0 \) partially coherent
\( \rho = 0 \) non-coherent

Terminology for this presentation:

- Phase Coherent – coherence of near 1
- Phase Stable – coherence less than 1 but much greater than 0
- Phase Controlled – capability to adjust the phase offset between coherent signals.
Multi-channel systems exploit coherent relationships between signals

Non-Coherent Signal Simulation
- EW
  - Multiple Emitters

Coherent Signal Simulation
- Phased Array Antennas
  - Calibration
  - Tx and Rx integration testing
- RADAR
  - Geolocation
  - Multiple receiver systems
- MIMO (multiple input/multiple output)
  - High capacity communication systems

Radar: Target reflection as seen by multiple receivers in the time domain

- RF must be coherent for phase control
- Baseband must be coherent for time control

All received signals can have:
- \( t \) (time, delay), \( \phi \) (phase), \( A \) (amplitude), or \( f \) (frequency, Doppler)
  from original transmitted signal
Communications: Multiple Antenna Diversity Configurations

SISO

SIMO

MISO

MIMO

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Spatial Diversity Techniques

Switched Diversity

Maximal Ratio Combining

Transmit Diversity

Beamforming

Space Coding Techniques - MIMO

2 x 2 MIMO

\[ x_1 h_{11} + x_2 h_{21} \]

\[ x_1 h_{12} + x_2 h_{22} \]

Linear Channel

\[ H^{-1} \]

(DSP)
Phased Array Antennas & Beam Forming

Direction Finding

Phase Interferometer Angle of Arrival (AoA) Measurement
Geo-Location Application

Interferometric Synthetic Aperture Radar (InSAR) is used in monitoring the effects of earthquakes & floods, land subsidence, glaciers, crop sizes, etc. Phase coherent, spatially separated receiving system using multiple receivers to determine not only the position of a target but also provide a 3-D image. When testing the receivers, input signals to each antenna must be phase coherent.

Agenda

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Phase Matching Problems

Group Delay Considerations

- Phase & Amplitude Matching Changes with Frequency
- Group Delay is a Measure of Phase Change with Frequency
  - Amplitude changes also affect group delay characteristics
- Filter Group Delay Changes Rapidly Near the Pass-band Edge
- Phase & Amplitude Must Remain Stable!
Coherent LO Challenges

- LOs Must be Phase Coherent Between Receivers
- Conversion LO’s Must be ‘Phase Related’
- A Single Master Reference Source is Essential
- Coherent Requirements Complicate Synthesizers

Source Phase Noise Considerations

- Phase noise affects performance
- Reduces AoA precision
- Integrated RMS phase error
- Integration limits set to the bandwidth of the emitter
Non-Linear Coherent Signal Effects

The High Cost of Field Testing
**Agenda**

**Coherent Multi-Channel & Diversity Systems**

*Phase Coherency Between Multiple Signal Sources*

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**The Problem: Need complete control of relative phase, time, and frequency of multiple signals**

A common reference provides frequency coherence but not full phase coherence

Two separate synthesizer paths

Not coherent - phase drifts over time

10 MHz

Non-coherent Synthesizer

I/Q Mod

Output 1

Detector

ALC Loop

Synthesizer 1

Clock

Trigger

ARB

Non-coherent Synthesizer

I/Q Mod

Output 2

Detector

ALC Loop

Synthesizer 2

Clock

Trigger

ARB

**ARB timebase not synchronized**

Triggering can have up to 20 ns of timing error
Phase Variations

Phase Tracking is Not Perfect
**LO vs. Reference Locked Configurations**

Note the difference in the Time and Phase Offset scales.

Most of the phase drift in the coherent case can be attributed to the measuring receiver (2 channel scope).

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**Agenda**

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**LO Locked Phase Coherent System**

Multiple Coherent Outputs Using Synthesizer Split Technique

- **Timebase**
- **Synthesizer**
- **Power Splitter**
- **Detector**
- **ALC Loop**

**Key Points**

- Both are coherent
- Separate modulation chains
- Outputs 1 & 2 are constrained to have the same carrier frequency

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**LO Locked Phase Coherent System**

Baseband time and phase alignment

- **Coherent Synthesizer**
- **Timebase**
- **Trigger**
- **ARB**
- **Clock**
- **Power Splitter/Amp**
- **External Sample Clock**

**Key Points**

- RF coherency
- Trigger simultaneously for baseband time alignment
- Common sample clock enables baseband coherency

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**Notes**

- Doubles OK, No dividers!
- Single synthesizer path
- Both synthesizers are coherent
- Separate modulation chains
- Outputs 1 & 2 are constrained to have the same carrier frequency

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**Image Source**

Agilent Technologies

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**Page**

3-15
The Solution:
Using the baseband generator (AWG) to control phase time and frequency

Fixed phase offset due to group delay of components after synthesizer split

The phase offset of each signal generator can be corrected by changing the starting phase of the I/Q waveform

Fixed phase offset between sources changes with frequency, amplitude and temperature

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Frequency Reference Configurations for Phase Stability

Improved phase stability using two PSGs with option H1S

PSG with UNIX and H1S

1 GHz in (H1S)
1 GHz in (H1S connector)
10 MHz in

PSG with UNIX

10 MHz out
1 GHz out (UNIX)
1 GHz out (H1S connector)

Improved phase stability using a PSG with low phase noise option UNIX & a PSG with option H1S

PSG with H1S

10 MHz in
RF Out to CH1
RF Out to CH 2

PSG with UNIX and H1S

10 MHz out
RF Out to CH 1
RF Out to CH 2

Frequency Reference and Phase Coherence Options for the PSG

These options apply to both the E8257D & E8267D except H1G which is only available on the E8267D

External Reference

10 MHz
1 GHz

Option H1S

(1 GHz)

Sampler / Oscillator Loop

Fractional-N Synthesizer

Divide to achieve frequencies below 3.2 GHz

Option HCC > 3.2 GHz

Out

In

Doubler

Option HCC

250 MHz - 3.2 GHz

Out

In

Phase stability for

100 kHz – 250 MHz

Reference

10 MHz Reference In

Reference

Out

In

Option H1G

Fine tunes frequency setting
Performance of the Phase Stable configuration

Bypassing the internal reference enables much improved phase stability (20 x improvement). Note the correlation in time of day suggesting room temperature and air conditioning play a big factor in the phase drift.

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N5182A MXG Phase Coherency (Option 012)
Two unit configuration

Signal Studio Software
N7615B or N7617B for MIMO applications

Phase Coherency on N5182A MXG (Option 012)
3 to 16 unit configuration

Signal Studio Software
WLAN or LTE for MIMO applications
Baseband Synchronization

- Greys out for slave instruments.
- Remains active for master instrument.
- BBG sync automatically changes the trigger type to Trigger and Run if the current setting Free Run or Gated (they are unavailable choices while using BBG sync).

MXG Baseband Generator Time Alignment

- Now the BBGs are in synch and baseband timing is aligned:
  - Oversampling issue resolved
  - Phase delay due to electrical lengths resolved
Phase Shift Capability

Analog phase shift for standalone operation (ESG, PSG, MXG)

Will not independently adjust the phase of the waveform in a phase coherent configuration

Vector phase shift for phase coherent operation (MXG)

Independently adjusts the phase of phase coherent MXG signal generators without updating the waveform

CW Phase Adjustment

Modifying and downloading a new waveform file is not needed to adjust MXG phase coherent offsets
Baseband Synchronization and Phase Coherence

PSG Coherent Source Solutions

Phase Coherent configurations from Agilent can accommodate up to 16 sources
**Time Align the Baseband Sampling**

Ensure all the AWGs start on the same sample

**Before alignment**

Oversampling of the BB waveform can and will introduce timing errors that need to be addressed

**After alignment**

Generate Wideband Waveforms to 44 GHz

External Wideband AWG

**N6030A(PXI) or N8241A(LXI) AWGs**

- 1 GHz I/O Bandwidth (using a dual channel configuration)
- 500 MHz IF only (for a single channel)
- 1.25 GS/s sample rate and 15 bit resolution
- Expanded waveform memory and advanced sequencing engine
- Nanosecond switching speeds within a 1 GHz bandwidth
- Generate phase coherent signals with a 1 GHz bandwidth
  - Multitone
  - Multichannel

500 MHz BW at 10 GHz:
13 bit Barker + Chirp + CW pulse
What Multi-Source Phase Coherency Does Not Do: Limitations of this solution

- **Lock to external source**
  - Does not have the ability to be phase coherent with an external synthesizer such as the COHO (coherent oscillator) of a transmitting RADAR. Generally a Digital RF Memory (DRFM) is used in this case.

- **Phase coherent frequency hopping**
  - Does not have the ability to change from frequency 1 to frequency 2 and then back to frequency 1 while have the same phase trajectory as when you left frequency 1 (except the case where we use the AWG to generate the frequency offset).
Waveform Creation Software Needed

Time & phase alignment
- Measure with network analyzer or oscilloscope
- Shift waveform to time and phase align
  » Embedded phase shift capability in the MXG
  » Add phase shift in waveform file

Waveform creation software
- Agilent Signal Studio for pulse building
- MATLAB
- ADS

I/Q Waveform Polar & Rectangular Representation
### Adding Phase to a Waveform File

A waveform file is made up of a series of I/Q pairs

1. \[ |A| = \sqrt{I^2 + Q^2} \] 
   Where \( A \) is the baseband waveform amplitude

2. \[ A = I + jQ \] 
   Complex representation

3. \[ A = |A|(\cos \theta + j\sin \theta) \] 
   \( A \) & \( Q \) are the polar coordinates of the I & Q pair

- To add phase \( \phi \) to the I/Q constellation Phasor \( Q \), multiply (3) by \( (\cos \phi + j\sin \phi) \)
- Convert back to the form of (2) getting \( A = I' + jQ' \)
- Scaling of the new waveform (I'/Q' pairs) will be required to maintain the identity (1) where “A” must remain constant

### Agenda

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  - Agilent phase coherent solutions
- Multi-channel receiver measurements
Dual Channel 89600 Vector Signal Analyzer

- Dual Coherent Channels
- Cross Channel Measurements
  - Coherence
  - Correlation
  - Cross Spectrum
  - Frequency Response
  - Impulse Response

TDoA Measurements

- Time Difference Measurements
- <1 nsec of Accuracy Freq. Domain
- Broadband Delay Matching
- Calibrated Flat Group Delay
- Complete Pulse Analysis
- Signal Studio Software
- Trace Math & .NET Capability
Coherent Interferometer Measurements

- Channel Phase Difference
- Need a Phase Meter
- Phasor Diagram
- I/Q Display Shows Phase!

Summary and Conclusion

- Many Antenna Apertures are Better than One
- Combat Multi-path, Form Beams & Direction Find
- Coherent Signals Create Added Test Challenges
- Agilent Offers Coherent Sources and Analyzers!
Web References

www.agilent.com/find/signalgenerators
www.agilent.com/find/PSG
www.agilent.com/find/ESG
www.agilent.com/find/MXG
www.agilent.com/find/signalstudio
www.agilent.com/find/AWG
www.agilent.com/find/scopes
www.agilent.com/find/89600
www.agilent.com/find/PNA
www.agilent.com/find/downloadassistant
www.agilent.com/find/AD

Q & A
Phase Drift Performance of Phase Stable Systems
Frequency coherence with a common reference

Phase drift measured on two PSGs with the 10 MHz reference connected. Once they are warmed up the drift is around 6 deg/hr or more. Better performance (less than 1 deg/hr) can be obtained by using the 1 GHz reference option (H1S) on the Agilent PSG (internal reference board bypass).

Note that phase stable configurations allow independent output frequency settings and analog phase adjustments (phase coherent systems do not).

Temperature variation is the primary factor in multi-source phase stability.
Multiple Antennas Improve Capacity

\[ C \approx B \log_2 \left( \frac{\hat{a}_e}{\hat{e}} \right) + \frac{S}{N} \]

Multipath Increases Number of Unique Spatial Channels

Environments with High Dynamics

- 6 Antennas Get 360° View
- Greater Antenna Gain!
- Antennas Must be Selected
- Switched Approach
- Matrix Approach

k \text{ equals } \# \text{ of antenna pairs}
Phase Stability Measurements
1 PSG with UNX & 1 PSG with H1S

Phase difference after 8 hours:
-0.030 radian or -1.7 degrees
Agilent E8257D PSG
Microwave Analog Signal Generator

Option 521 Ultrahigh Output Power,
Frequency Range From 10 MHz to 20 GHz

Breaking the One-Watt Output Power Barrier

- **Delivers** output power > 1 W (typical) and up to +28 dBm (specified)
- **Eliminates** the need for external switches, amplifiers, couplers, and detectors
- **Meets** power requirements for TWT amplifier evaluation, automated test systems, and antenna testing
The E8257D PSG is the industry’s first microwave analog signal generator to deliver greater than one watt of typical output power. Traditionally, achieving calibrated power levels above +25 dBm over a broad bandwidth up to 20 GHz in an automated system environment requires complex and expensive RF hardware. The PSG with Option 521 dramatically simplifies this high-power test environment, providing greater than +25 dBm of specified output power in a single test instrument. The PSG also protects the power sensitive devices in your system with a built-in power level clamp that can be set from +15 to +33 dBm.

The PSG equipped with Option 521 provides the specified output power required for TWT amplifier evaluation, automated test systems and antenna testing, but also eliminates custom hardware and software development, reduces the physical footprint of the test system, simplifies system calibration, and most importantly reduces your overall cost of ownership over the lifetime of your test program.

---

**Preliminary Specification Summary**

<table>
<thead>
<tr>
<th>Minimum output power (dBm)</th>
<th>Standard</th>
<th>-15 (settable to -20)</th>
<th>With Option 1E1 step attenuator</th>
<th>-130 (settable to -135)</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Maximum output power (dBm)</th>
<th>Frequency range</th>
<th>Standard</th>
<th>Option 1E1</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 to 250 MHz</td>
<td>+18 (+21 typ)</td>
<td>+18 (+21 typ)</td>
<td></td>
</tr>
<tr>
<td>&gt; 0.25 to 1 GHz</td>
<td>+24 (+27 typ)</td>
<td>+24 (+27 typ)</td>
<td></td>
</tr>
<tr>
<td>&gt; 1 to 6 GHz</td>
<td>+28 (+31 typ)</td>
<td>+27 (+30 typ)</td>
<td></td>
</tr>
<tr>
<td>&gt; 6 to 14 GHz</td>
<td>+26 (+29 typ)</td>
<td>+25 (+28 typ)</td>
<td></td>
</tr>
<tr>
<td>&gt; 14 to 18.6 GHz</td>
<td>+25 (+28 typ)</td>
<td>+24 (+27 typ)</td>
<td></td>
</tr>
<tr>
<td>&gt; 18.6 to 20 GHz</td>
<td>+24 (+27 typ)</td>
<td>+23 (+26 typ)</td>
<td></td>
</tr>
</tbody>
</table>

**Level accuracy (dB)**

<table>
<thead>
<tr>
<th>Frequency range</th>
<th>&gt; 20 dBm</th>
<th>20 to 16 dBm</th>
<th>16 to 10 dBm</th>
<th>10 to 0 dBm</th>
<th>0 to -10 dBm</th>
<th>-10 to -17 dBm</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 to &lt; 500 MHz</td>
<td>—</td>
<td>±1.2 (typ)</td>
<td>±1.2 (typ)</td>
<td>±1.1 (typ)</td>
<td>±1.2 (typ)</td>
<td>±1.3 (typ)</td>
</tr>
<tr>
<td>0.5 to 20 GHz</td>
<td>±1.0</td>
<td>±0.8</td>
<td>±0.8</td>
<td>±0.6</td>
<td>±0.8</td>
<td>±1.2</td>
</tr>
</tbody>
</table>

**Level accuracy with step attenuator (Option 1E1) (dB)**

<table>
<thead>
<tr>
<th>Frequency range</th>
<th>&gt; 20 dBm</th>
<th>20 to 16 dBm</th>
<th>16 to 10 dBm</th>
<th>10 to 0 dBm</th>
<th>0 to -10 dBm</th>
<th>-10 to -70 dBm</th>
<th>-70 to -90 dBm</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 to &lt; 500 MHz</td>
<td>—</td>
<td>±1.0</td>
<td>±0.9</td>
<td>±0.9</td>
<td>±0.9</td>
<td>±1.0</td>
<td>±1.1</td>
</tr>
<tr>
<td>0.5 to 20 GHz</td>
<td>±1.0</td>
<td>±0.8</td>
<td>±0.8</td>
<td>±0.8</td>
<td>±0.8</td>
<td>±0.9</td>
<td>±1.0</td>
</tr>
</tbody>
</table>

**Harmonics**

- 10 to 50 MHz | -25 dBc
- 10 to 50 MHz with filters on | -35 dBc
- 0.05 to 2 GHz | -25 dBc
- 2 to 20 GHz | -35 dBc

---

1. Specifications are preliminary and are subject to change without notice.
2. Specifications below 500 MHz are typical and apply for a 50-Ω load with VSWR less than 1.4:1. With filters off, accuracy is typically ±2 dB.
3. Specification below 500 MHz apply with the step attenuator set to 5 dB or higher (requiring Attenuator Hold ON above 8 dBm). With step attenuator set to 0 dB, refer to level accuracy specifications without Option 1E1.

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