Back to Basics: Signal Generation
Agenda

- The need for creating test signals
  - Aerospace Defense to Communications
- Generating Signals
  - No modulation
  - Analog Modulation
  - Composite Modulation
- Signal Generator Architecture
- Signal Simulation Solutions
- Summary
From Movies ....

Nov. 1940 - News Flash

Disney releases Fantasia with "Fantasound", a new audio stereophonic sound system

Walt Disney orders eight audio oscillators (HP 200B) for the sound production of the movie Fantasia.

The 200B was used to calibrate the breakthrough sound system of Walt Disney’s celebrated animated film, Fantasia
Aerospace Defense ....

TESTING RADAR TRANSMITTERS and RECEIVERS

Signal Processor (range and Doppler)

RF Signal Injection

IF Signal Injection

LO Substitution

Antenna

LNA

1st LO

2nd IFA

1st IFA

IF BPF

2nd LO

2nd IFA

IF BPF

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To Mobile Communications….

TESTING DIGITAL TRANSMITTERS and RECEIVERS

RF Signal injection
IF Signal Injection
Baseband Signal Injection
Agenda

- The need for creating test signals
  - Aerospace Defense to Communications

- Generating Signals
  - No modulation
  - Analog Modulation
  - Composite Modulation

- Signal Generator Architecture

- Signal Simulation Solutions

- Summary
Generating Signals – No Modulation

The sine wave is the basic, non-modulated signal: It is useful for stimulus/response testing of linear components and for Local Oscillator substitution. Available frequencies range from low RF to Millimeter.
Generating Signals – Analog Modulation

Modulation: Where the Information Resides

\[ V(t) = A(t) \cdot \cos(2\pi f_c t + \Phi(t)) \]

AM, Pulse

FM, PM
Generating Signals - Analog Modulation

Amplitude Modulation

Important Characteristics for Amplitude Modulation

- Modulation frequency (rate)
- Depth of modulation (Mod Index)
- Linear AM (%)
- Log AM (dB)
- Sensitivity (depth/volt)
- Distortion %

Where are AM signals used?

- AM Radio
- Antenna scan
- ASK (early digital 100101)
Generating Signals – Analog Modulation

Frequency Modulation

\[ V(t) = A \cos(2\pi f_c t + \beta \sin2\pi F_m t) \]

\( \beta \) is the modulation index, where \( \beta = \frac{\Delta F_{\text{dev}}}{F_m} \)

Important Characteristics for Frequency Modulation

- Frequency Deviation (\( \Delta F_{\text{dev}} \))
- Modulation Frequency (\( F_m \))
- Accuracy
- Resolution
- Distortion (%)
- Sensitivity (dev/volt)
Generating Signals – Analog Modulation

**Phase Modulation**

\[ V(t) = A \cos[2\pi f_c t + \beta 2\pi F_m t] \]

Where \( \beta = \Delta \theta \), the peak phase deviation

**Important Characteristics for Phase Modulation**
- Phase deviation (\( \Delta \theta \))
- Modulation Rate (\( F_m \))
- Accuracy
- Resolution
- Distortion (%)
- Sensitivity (dev/volt)

Where are Phase Modulated signals used?
- PSK (early digital 1010)
- Radar (pulse coding)
Generating Signals – Analog Modulation

Pulse Modulation

Important Characteristics for Pulse Modulation
- Pulse width \( t \)
- PRF \( 1/T \)
- Duty cycle \( t/T \)
- On/Off ratio (dB)
- Rise time (ns)

Where are Pulse Modulated signals used?
- Radar
- High Power Stimulus/Response
- Communications
Generating Signals – Composite Modulation

Simultaneous modulation of two Mod Types

Independent Amplitude and Phase Modulation

Integrated IQ Modulator

Independent FM and Pulse Modulation

32 QAM Constellation Diagram

FM during the pulse = chirp
Generating Signals – Composite Modulation

Vector Signal Changes or Modifications

Magnitude Change

Phase Change

Both Change

Frequency Change

Generating Signals – Composite Modulation

Vector Signal Changes or Modifications

Magnitude Change

Phase Change

Both Change

Frequency Change
Generating Signals – Composite Modulation

Polar Versus I-Q Format

- Project Signals to “I” and “Q” Axes
- Polar to Rectangular Conversion
- IQ Plane Shows 2 Things:
  - What the modulated carrier is doing relative to the unmodulated carrier.
  - What baseband I and Q inputs are required to produce the modulated carrier
Generating Signals – Composite Modulation

**Transmitting Digital Data -- Bits vs Symbols**

**Binary Data bit = 0, 1**

Transmitting Digital Bits (\( f_1 = 0, f_2 = 1 \))

\[
f(t) = \begin{cases} 
  f_1 & \text{for } 010101010 \\
  f_2 & \text{for } T
\end{cases}
\]

Symbol = Groups/blocks of Bits

2 bits/symbol (00 01 10 11)
3 bits/symbol (000 001 ....)
4 bits/symbol (0000 0001 ..)

**Transmission Bandwidth Required**

Main lobe width is 2

\[
\frac{2}{T}
\]

Sample rate

**Symbol Rate** \( = \frac{\text{Bit rate}}{\# \text{ bits per symbol}}\)

Main lobe width is 2

\[
\frac{2}{S}
\]

Symbol rate

**Notes:**

- \( f(t) \) represents the transmitted signal.
- \( f_1 \) and \( f_2 \) are the two carrier frequencies.
- Binary data bits 0 and 1 are represented as different waveforms.
- Symbols are groupings of bits, with 2, 3, and 4 bits per symbol.
- Transmission bandwidth is determined by the main lobe width of the signal spectrum.
- Symbol rate is calculated based on the bit rate and the number of bits per symbol.
### Digital Modulation Characteristics

<table>
<thead>
<tr>
<th>Modulation format</th>
<th>Number of bits per symbol</th>
<th>Constellation</th>
<th>Transmission bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPSK</td>
<td>1</td>
<td><img src="image" alt="BPSK Constellation" /></td>
<td><img src="image" alt="BPSK Bandwidth" /></td>
</tr>
<tr>
<td>QPSK</td>
<td>2</td>
<td><img src="image" alt="QPSK Constellation" /></td>
<td><img src="image" alt="QPSK Bandwidth" /></td>
</tr>
<tr>
<td>16 QAM</td>
<td>4</td>
<td><img src="image" alt="16 QAM Constellation" /></td>
<td><img src="image" alt="16 QAM Bandwidth" /></td>
</tr>
</tbody>
</table>

Symbol Rate = \#symbols/sec. (Hz)
Vector Modulation - Important Characteristics

- IQ Modulation Bandwidth
- Frequency Response/flatness
- IQ quadrature skew
- IQ gain balance

Generating Signals – Composite Modulation
Generating Signals – Composite Modulation

Vector Modulation - Where Used

- Mobile Digital Communications
- Modern Radars
Agenda

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Signal Generator Architecture

Basic CW Signals

• Block Diagram (RF and Microwave)
• Specifications
• Applications

Analog Signals

• Block Diagram (AM, FM, PM, Pulse)
• Applications

Vector Signals

• Block Diagram (IQ)
• Applications
Basic CW Signals – Block Diagram

RF Source

Synthesizer Section

Reference Section

Output Section

Reference Oscillator

divide by X

f

Phase Detector

Frac-N

VCO

ALC Modulator

Output Attenuator

ALC Driver

ALC Detector

ALC = automatic level control
Basic CW Signals – Block Diagram

Reference Section

<table>
<thead>
<tr>
<th></th>
<th>TCXO</th>
<th>OCXO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aging Rate</td>
<td>+/- 2ppm/year</td>
<td>+/- 0.1 ppm /year</td>
</tr>
<tr>
<td>Temp.</td>
<td>+/- 1ppm</td>
<td>+/- 0.01 ppm</td>
</tr>
<tr>
<td>Line Voltage</td>
<td>+/- 0.5ppm</td>
<td>+/- 0.001 ppm</td>
</tr>
</tbody>
</table>
Basic CW Signals – Block Diagram

Output Section

- **ALC**
  - maintains level output power by adding/subtracting power as needed

- **Output Attenuator**
  - mechanical or electronic
  - provides attenuation to achieve wide output range (e.g. -127 dBm to +23 dBm)
Basic CW Signals – Block Diagram

Synthesizer Section

- **N = 93.1**
- **Frac-N**
- **Error signal**
- **5MHz**
- **5MHz**
- **From reference section**
- **Phase Detector**
- **VCO**
- **x 2 Multiplier**
- **465.5 MHz**
- **931 MHz**
- **Front panel control**
- **To output section**
Basic CW Signals – Block Diagram

PLL/Fractional-N...suppress phase noise

Overall phase noise of signal

Phase-locked-loop (PLL) bandwidth selected for optimum noise performance

Reference oscillator

20logN

Phase detector noise

Broadband noise floor

VCO noise

frequency
Basic CW Signals – Block Diagram

Microwave Source

Reference Section
- Ref Osc
- Phase Det
- Frac N

Synthesizer Section
- Phase Detector
- Frac N
- VCO

Output Section
- ALC Modulator
- Output Attenuator
- ALC Driver
- ALC Detector
Basic CW Signals – Specifications

**Frequency**

- **Range** $F_{\text{min}}$ to $F_{\text{max}}$
- **Resolution** Smallest frequency increment
- **Accuracy** How close is the indicated frequency to the actual frequency?
- **Switching Speed** How quickly can you change from one frequency to another?

Accuracy = $f_{\text{CW}} \cdot t_{\text{aging}} \cdot t_{\text{cal}}$

- $f_{\text{CW}} = 1 \text{ GHz}$ (CW frequency)
- $t_{\text{aging}} = 0.152 \text{ ppm/year}$ (aging rate)
- $t_{\text{cal}} = 1 \text{ year}$ (time since last calibrated)

Accuracy = 152 Hz
Basic CW Signals – Specifications

Amplitude

- **Range**  $P_{\text{min}}$ to $P_{\text{max}}$
- **Resolution**  Smallest amplitude increment
- **Accuracy**  How close is the indicated amplitude to the actual amplitude?
- **Switching Speed**  How quickly can you change from one amplitude to another?
- **Reverse Power Protection**  Maximum safe power that can be applied to the RF output

Source protected from accidental transmission from DUT
Basic CW Signals – Specifications

Frequency Sweep

Step sweep
- accuracy
- number of points
- switching time

Ramp sweep
- accuracy
- sweep time
- resolution
Basic CW Signals – Specifications

Frequency Sweep
- Level Accuracy
- Flatness
- Source Match (SWR)

Power Sweep
- Power Sweep Range
- Power Slope Range
- Source Match (SWR)
Basic CW Signals – Specifications

Spectral Purity

- Phase Noise
- Spurious
- Harmonics
- Sub-harmonics

Sub-harmonics

Phase noise, dBc/Hz

Non-harmonic spur ~65dBc

Harmonic spur ~30dBc

CW output
Poor frequency accuracy and/or resolution will cause the transmitter output to be at the wrong frequency.

Poor phase noise spreads energy into adjacent channels.

**Key Specs:**
- Frequency Range
- Accuracy
- Resolution
- Output Power
- Phase Noise
Basic CW Signals – Applications

In-Channel Receiver Testing

The smallest RF signal that will produce a desired baseband output from the receiver

Key Specs:

- Amplitude Range
- Amplitude Accuracy
- Amplitude Resolution

Receiver Sensitivity

IF Rejection Curve

-116 dBm to -126 dBm

IF Channel

Level (dBm)

Frequency
Basic CW Signals – Applications

Out-of-channel Receiver Testing

Receiver Selectivity
Spurious Response Immunity

Key Specs:
- Frequency Range
- Output Power
- Phase Noise
- Broadband noise
- Non-harmonic spurious

spur from source and/or high levels of phase noise can cause a good receiver to fail
Basic CW Signals – Applications

Non-linear Amplifier Testing - TOI

Key Specs:
- Frequency Range
- Frequency Accuracy
- Frequency Resolution
- Output Power
- Non-harmonic spurious

Two-tone Intermodulation Distortion

output RF

\[ f_1 \]
\[ f_2 \]

isolator

DUT

\[ f_L = 2f_1 - f_2 \]
\[ f_U = 2f_2 - f_1 \]

amplitude

frequency

test system third order products will also fall here

spurious signals from source can corrupt measurement
Basic CW Signals – Applications

Out-of-channel Receiver Testing - IMD

Key Specs:
- Frequency Range
- Frequency Accuracy
- Frequency Resolution
- Output Power
- Non-harmonic spurious

IF signal out-of-channel signals

Fmod = nF1 + mF2
n = -1,2
m = 2, -1

IF Rejection Curve

Intermodulation immunity

DUT

Sources output

spur from source

Intermodulation product
Fmod = 2F2 – F1

Level (dBm)

Frequency

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Basic CW Signals – Applications

Stimulus-Response Testing

Example DUT’s

\[ F_{\text{in}} \rightarrow F_{\text{out}} \]

\[ \text{LO} \]

\[ F_{\text{in}} \rightarrow F_{\text{out}} \]

Key Specs:

- Frequency Range
- Frequency Accuracy
- Frequency Ramp/step sweep
- Power sweep
- Sweep speed
- Output Power accuracy
- Residual FM
Signal Generators

Basic CW Signals
  • Block Diagram (RF and Microwave)
  • Specifications
  • Applications

Analog Signals
  • Block Diagram (AM, FM, PM, Pulse)
  • Applications

Vector Signals
  • Block Diagram (IQ)
  • Applications
Add AM, FM, PM, and Pulse Modulation

- VCO
- Frequency Control
- Reference Oscillator
- FM, PM input
- AM input
- Pulse Mod input
- ALC Modulator
- ALC Driver
- Pulse Mod.
- Output Attenuator
Add internal modulation generator

- VCO
- Freq. Control
- Reference Oscillator
- FM, PM input
- AM input
- Pulse Mod input
- ALC Modulator
- Pulse Mod.
- ALC Driver
- Output Attenuator
- FM Source
- AM Source
- Pulse Source
Analog Signals – Applications

Pulsed Radar Testing with Chirps

FM during the pulse = chirp

Key Specs:

- Frequency Range
- FM Modulation rate/deviation
- Pulse rate, width, rise time

Analog Signals – Applications

Pulsed Radar Testing with Chirps

FM during the pulse = chirp

Key Specs:

- Frequency Range
- FM Modulation rate/deviation
- Pulse rate, width, rise time
Signal Generators

Basic CW Signals

• Block Diagram (RF and Microwave)
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Analog Signals

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• Applications

Vector Signals

• Block Diagram (IQ)
• Applications
Vector Signals – Block Diagram

**IQ Modulation**

- Good Interface with Digital Signals and Circuits
- Can be Implemented with Simple Circuits
- Fast, accurate state change
Vector Signals – Block Diagram

Adding the IQ modulator

Synthesizer

I-Q Modulator

Output

Freq. Control

VCO

Reference

\[ 90° \]

\[ \sum \]

\[ \text{ALC Driver} \]

\[ \text{ALC Driver} \]

\[ I \]

\[ Q \]
**Vector Signals – Block Diagram**

**Baseband IQ signal generation**

- **Pattern RAM**
- **Symbol Mapping and Baseband Filters**
  - `00 -> 1+j1`
  - `01 -> -1+j1`
  - `10 -> -1-j1`
  - `11 -> 1-j1`

- **Analog Reconstruction Filters**
  - DAC
  - DAC
  - `I` and `Q` outputs

![Graph showing vector signals](image)
Vector Signals – Block Diagram

Baseband Generator: Baseband Filters

Fast Transitions Require Wide Bandwidths

Filtering Slows Down Transitions and Narrows the Bandwidth
Adding an internal Baseband Generator

Synthesizer

VCO
Freq. Control
Reference

I-Q Modulator
p/2

Output

ALC Driver

Baseband Generator

Pattern RAM and Symbol Mapping

DAC
DAC

Vector Signals – Block Diagram
Vector Signals – Applications

Format Specific Signal Generation
Receiver Sensitivity
Receiver Selectivity
Component Distortion
Vector Signals – Applications

Digital Format Access Schemes

**FDMA**
- One User
- Differ channel - different Users

**TDMA**
- Different time - different Users

**CDMA**
- Same channel – many users

**OFDM**
- Different time - different Users
Vector Signals – Applications

Format Specific Modulation

**GSM:** A type of TDMA modulation
Multiple users, same frequency, different time slots
Vector Signals – Applications

Digital Receiver Sensitivity

The smallest modulated RF signal that will produce a specified BER from the receiver
Testing a -110 dB sensitivity digital receiver:

X = Failed unit
0 = Passed unit

Case 1: Source has +/- 5 dB of output power accuracy at -100 to -120 dBm output power.

Set source to -115 dBm
Actual output power = -114 dBm

Case 2: Source has +/- 1 dB of output power accuracy at -100 to -120 dBm output power.

Set source to -111 dBm
Actual output power = -112 dBm
Vector Signals – Applications

Receiver Selectivity (Blocking Tests)

Spur from source and/or high levels of phase noise can cause a good receiver to fail.
Vector Signals – Applications

Receiver Sensitivity – Connected Solutions

- Simulated portion

RF

IF

Demodulator

A/D Converter

Baseband De-Coding

DUT

RF/IF BER

Signal Generator

Simulation Software

Signal Analyzer

RF

IF

Agilent Technologies
Component Distortion – Adjacent Channel Power Ratio

<table>
<thead>
<tr>
<th>Margin (dB)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>10</th>
<th>15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Error contribution (dB)</td>
<td>3.0</td>
<td>2.5</td>
<td>2.1</td>
<td>1.8</td>
<td>1.5</td>
<td>1.2</td>
<td><strong>0.4</strong></td>
<td><strong>0.2</strong></td>
</tr>
</tbody>
</table>
Component Distortion – Error Vector Magnitude

OFDM Signal - 400 MHz Bandwidth

Magnitude Error (IQ error mag)
Test Signal
Error Vector Magnitude

Ideal (Reference) Signal
Phase Error (IQ error phase)
Component Distortion – EVM

Measured EVM = -30 dB, 3.3%

OFDM Signal -
400 MHz Bandwidth

Agilent 89600 Vector Signal Analyzer

EVM = -29.538 dB
PilotEVM = -23.042 dB
Freq. Err = 10.702 Hz
Quad. Err = 339.07 mrad
Sync. Corr = 0.90318
Mod. Freq. = QPSK
Dots/Sec = 1059
Code Rate = 3/4

Vector Signals – Applications

Anticipate Accelerate Achieve

Agilent Technologies

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Signal Simulation Solutions

Remove Test Signal Imperfections

Sources of error – I/Q modulator, RF chain, IQ path
Result – passband tilt, ripple, and roll off
Remove Test Signal imperfections – IQ flatness

Solution – measure vector signal generator and apply predistortion

Tradeoff – calculation time, valid calibration time

Typical application – wideband, multitone, and multicarrier

32 tones - 80 MHz

2.4 dB Before 6-8 dB

0.1 dB After < 3 dB

500 MHz UWB
Removing Test Signal Imperfections - IMD

**Before Predistortion**
Measured in-band IMD = -40 dBc

**After Predistortion**
Measured in-band IMD = -84 dBc
Removing Test Signal Imperfections – Group Delay

Before Predistortion
EVM -30 dB, 3.3%

After Predistortion
EVM –34 dB, 2%
Non-linear Amplifier Testing

- Improved IMD suppression (typically > 80 dBc)
- Correct generator with additional devices in the loop
- Lower overall cost-of-test for large # tones
- Same hardware for ACPR/NPR distortion tests

Signal Studio – Enhanced Multitone

- Up to 1024 tones
- Set relative tone phase
- 80 MHz correction BW
- CCDF plot

Intermodulation Distortion
SISO BBG and Fading Test at RF/BB

1. PXB generates single channel signals with long playback
2. PXB applies SISO real-time fading
3. Output IQ or RF

- Analog I/Q
- N5102A Digital I/Q
- Vector MXG, EXG, ESG, or PSG used as an up converter

No BBG required for MXG or EXG

Transmission channel

Faded signal & Interferers

Receiver

BER/PER analysis
MIMO Receiver Test at RF/BB

Create MIMO signals with real-time fading for receiver test

1. PXB generates MIMO signals up to 4x2 with long playback.

2. PXB applies flexible real-time fading to MIMO signals.

3. No BBG required for MXG or EXG.

Vector MXG, EXG or ESG used as RF up converters, one per receive antenna.

Mobile Station

Rx0

Rx1
Agenda

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### Agilent Portfolio Summary

#### Performance

**RF**
- **N9310A**
  - 3 GHz

**MW**
- **N5183A MXG**
  - 20, 32, or 40 GHz
  - Fast switching

#### Mid-Performance

**RF**
- **N5171B EXG**
  - 1.3, or 6 GHz
  - High power & Fast switching

**MW**
- **N5183A MXG**
  - 20, 32, or 40 GHz
  - Fast switching

#### High Performance

**RF**
- **N5181B MXG**
  - 3 or 6 GHz
  - Spectral purity

**RF**
- **E8663D**
  - 3.2 or 9 GHz
  - World class SSB phase noise

**RF**
- **E8257D PSG**
  - 20, 32, 40, or 67 GHz
  - Extensions up to 325 GHz
  - World class SSB phase noise

**MW**
- **E8257D PSG**
  - 20, 32, or 44 GHz
  - High power
  - World class SSB phase noise

#### Analog & Digital I/Q

**RF**
- **N9310A**
  - 3 GHz
  - External I/Q only
  - 80 MHz ext I/Q BW

**RF**
- **N5172B EXG**
  - 3 or 6 GHz
  - High power and ACPR
  - Fast switching
  - Real-time & ARB BBG
  - 3G, LTE, GNSS, WLAN, Digital Video, and more

**BB**
- **N5106A PXB**
  - Analog & Digital I/Q outputs
  - Multi-channel BBG
  - Up to 8 real-time faders
  - Up to 24 paths per fader
  - Up to 4x2 MIMO
  - LTE, WiMAX, WLAN, Digital Video, and more

**RF**
- **N5182B MXG**
  - 3 or 6 GHz
  - Best power, ACP & EVM
  - Real-time & ARB BBG
  - 160 MHz BW
  - 3G, LTE, GNSS WLAN, Digital Video, and more

**RF**
- **E8267D PSG**
  - 20, 32, or 44 GHz
  - High power
  - World class SSB phase noise
  - 2 GHz ext I/Q BW
  - Real-time & ARB BBG
  - Digital I/Q I/O
  - Pulse building, NPR/multitone, 3G, WiMAX, WLAN, and more

**MW**
- **E8267D PSG**
  - 20,32,40, or 67 GHz
  - Extensions up to 325 GHz
  - Highest power (over 1 watt)
  - World class SSB phase noise

#### Signal Studio Software

- Anticipate
- Accelerate
- Achieve
Agilent Technologies RF Signal Generation

The New X-Series Signal Generators

MXG N5182B
Vector
9 kHz to 6 GHz

ESG E4428C
250 kHz to 6 GHz

MXG N5181B
Analog
9 kHz to 6 GHz

EXG N5172B
Vector
9 kHz to 6 GHz

EXG N5171B
Analog
9 kHz to 6 GHz

MXG N5182A
100 kHz to 6 GHz

MXG N5181A
100 kHz to 6 GHz

The Worlds Best
Performance

Most Sophisticated
Real-Time applications

Lowest Cost of Ownership

Code compatible
Millimeter Wave Signal Generation

- E8257D has the widest specified frequency range of any signal generator on the market: 250 kHz to 67 GHz

- E8257D offers 8 different models of mm source modules covering 50 to 500 GHz
  - 50 to 75 GHz
  - 60 to 90 GHz
  - 75 to 110 GHz
  - 90 to 140 GHz
  - 110 to 170 GHz
  - 140 to 220 GHz
  - 220 to 325 GHz
  - 325 to 500 GHz
Agilent Signal Studio & Embedded Software
Simplify Signal Creation – Validated & Performance Optimized

Cellular Communications
- LTE-Advanced FDD/TDD
- LTE FDD/TDD
- MSR (under LTE)
- W-CDMA/HSPA/HSPA+
- TD-SCDMA/HSPA
- GSM/EDGE/EDGE Evo
cdma2000/1xEV-DO

Wireless Connectivity
- 802.11ac WLAN
- 802.11n WLAN
- 802.11a/b/g/p/j WLAN
- 802.16 WiMAX
- Bluetooth
- MB-OFDM UWB

Audio/Video Broadcasting
- ATSC
- CMMB / DTMB
- DAB/DAB+
- DOCSIS
- DVB-T/T2/H/C/S/S2
- FM Stereo/RDS
- ISDB-T/TSB/Tmm
- J.83 Annex A/B/C
- S/T-DMB

Detection, Positioning, Tracking & Navigation
- GPS
- Glonass
- Galileo
- Pulse Builder

General RF & MW
- Toolkit
- Multitone
- Enhanced Multitone
- Noise Power Ratio
- Jitter Injection
- Phase Noise Impairment
- Noise (AWGN)
- Channel Emulation
- Analog & Digital Mod
- MATLAB

Platforms: RF/MW Signal Generators, Multi-Ch. BB Generator/Channel Emulator, DigRF Testers, Wideband ARBs, ADS, SystemVue, OBTs...
For Additional Information

Sources: [http://www.agilent.com/find/sources](http://www.agilent.com/find/sources)


Recorded webcast: [Back to Basics: Signal Analysis](http://www.agilent.com/find/sources)
THANK YOU!