Corso di Misure a Microonde

# Generatori a microonde
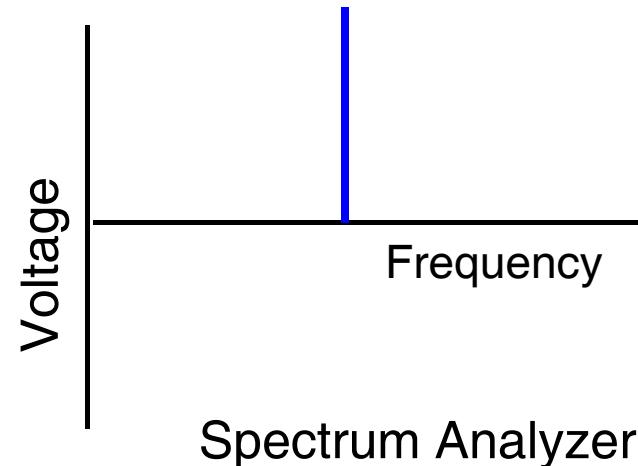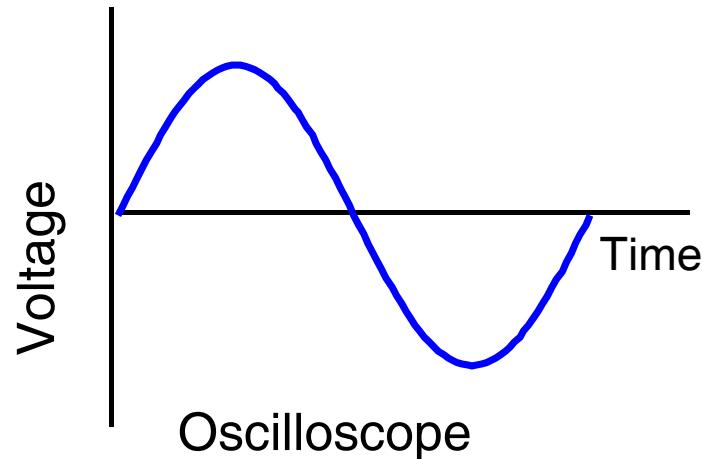
Prof. Luca Perregrini

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e-mail: luca.perregrini@unipv.it, web: microwave.unipv.it
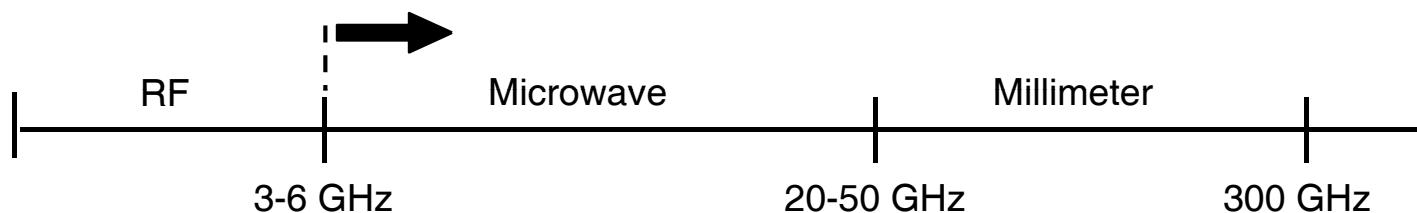
Sommario

- Tipologie: a onda continua (CW), variabili in frequenza (sweep), generatori di segnali

- Caratteristiche e schemi di funzionamento

Sources Generate Sine Waves

Voltage / Time

Oscilloscope

Voltage / Frequency

Spectrum Analyzer

This is the ideal output: most specs deal with deviations from the ideal and adding modulation to a sine wave

RF | Microwave | Millimeter

3-6 GHz   20-50 GHz   300 GHz

Types of sources
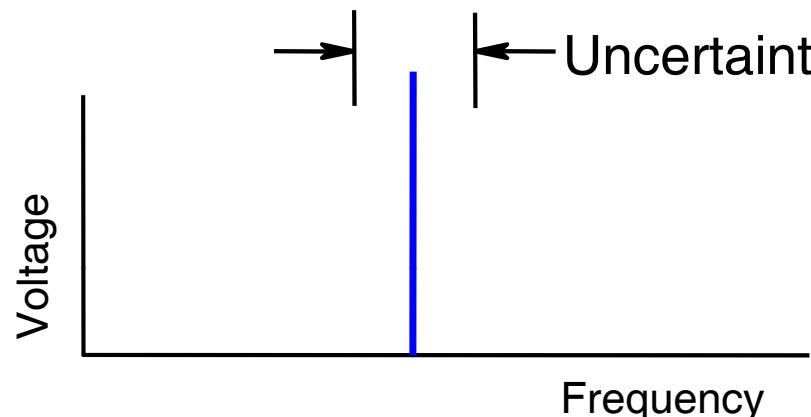
- ## CW
 - generates a single frequency, fixed sine wave
- ## Swept
  - sweeps over a range of frequencies
  - may be phase continuous
- ## Signal Generator
  - adds modulation
  - produces "real world" signal

CW source specifications: frequency

- Range: Range of frequencies covered by the source
- Resolution: Smallest frequency increment.
- Accuracy: How accurately can the source frequency be set.

EXAMPLE

Accuracy = $\pm\, f_{CW} *\, \tau_{aging} *\, \tau_{cal}$
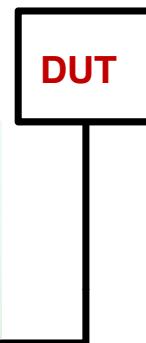
f_{CW} = CW frequency = 1 GHz
τ_{aging} = aging rate = 0.152 ppm/year
τ_{cal} = time since last calibrated = 1 year

→ Accuracy = $\pm$ 152 Hz

Uncertainty

Voltage

Frequency

CW source specifications: amplitude
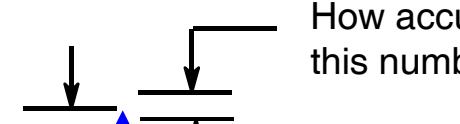
- Range (-136dBm to +13dBm)
- Accuracy (+/- 0.5dB)
- Resolution (0.02dB)
- Switching Speed (25ms)
- Reverse Power Protection

**Source protected from accidental transmission from DUT**

What is P_{max} out?
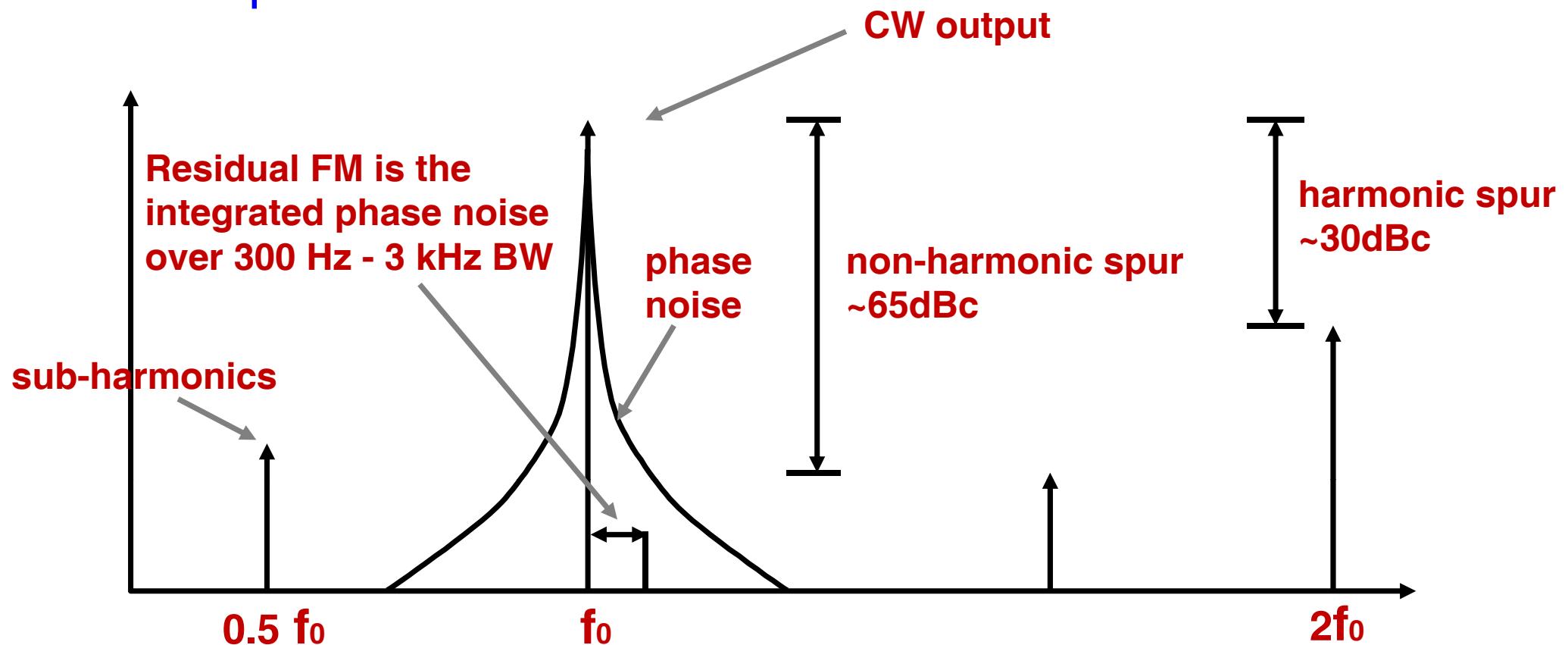
How accurate is this number?

Voltage

What is P_{min} out?

Frequency

DUT

CW source specifications: spectral purity

- Phase Noise
- Residual FM
- Spurious
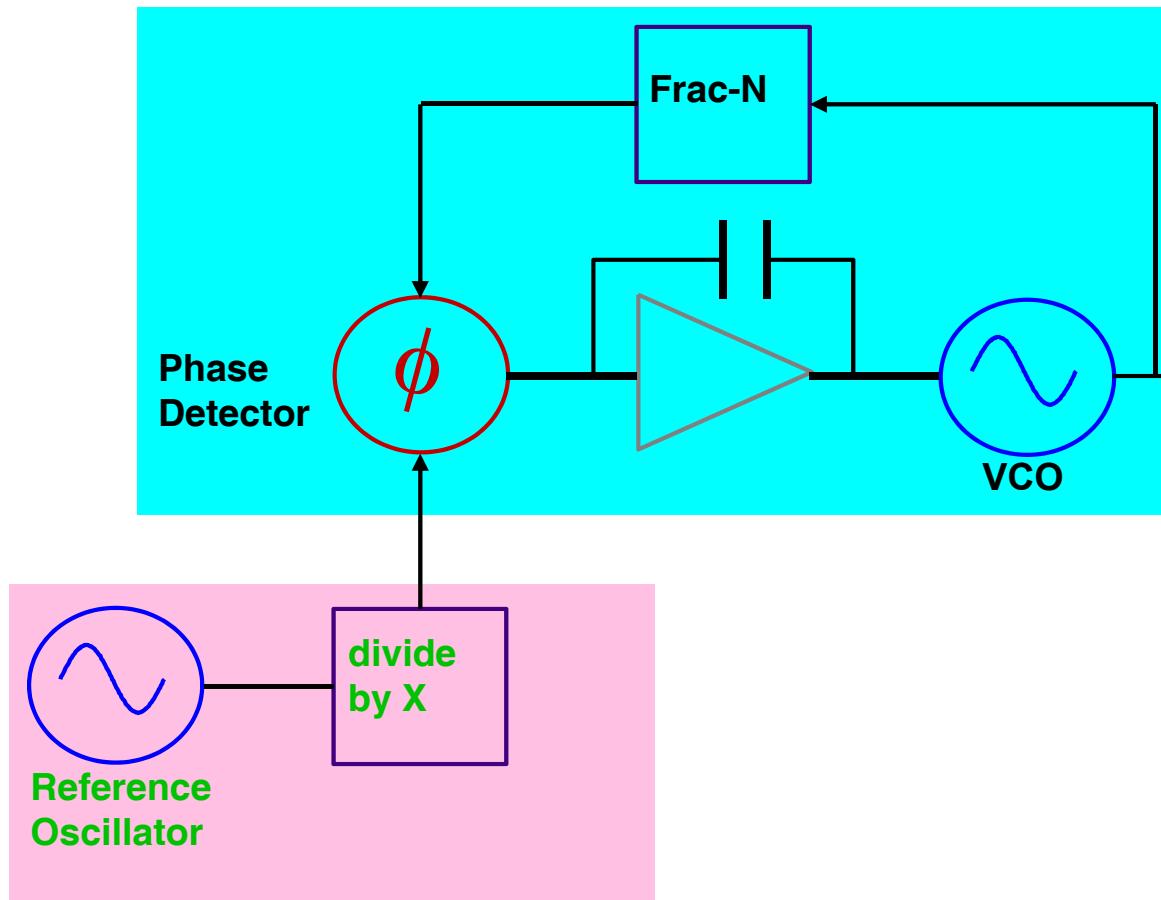
CW output

Residual FM is the integrated phase noise over 300 Hz - 3 kHz BW

phase noise

non-harmonic spur ~65dBc

harmonic spur ~30dBc

sub-harmonics

$0.5\ f_0$ f_0 $2f_0$

CW source specifications: Spectral Purity

Phase Noise

RF CW block diagram

Synthesizer Section

Frac-N

Phase Detector

ϕ

VCO

Output Section

ALC Modulator

Output Attenuator

ALC Driver

ALC Detector

Reference Oscillator

divide by X
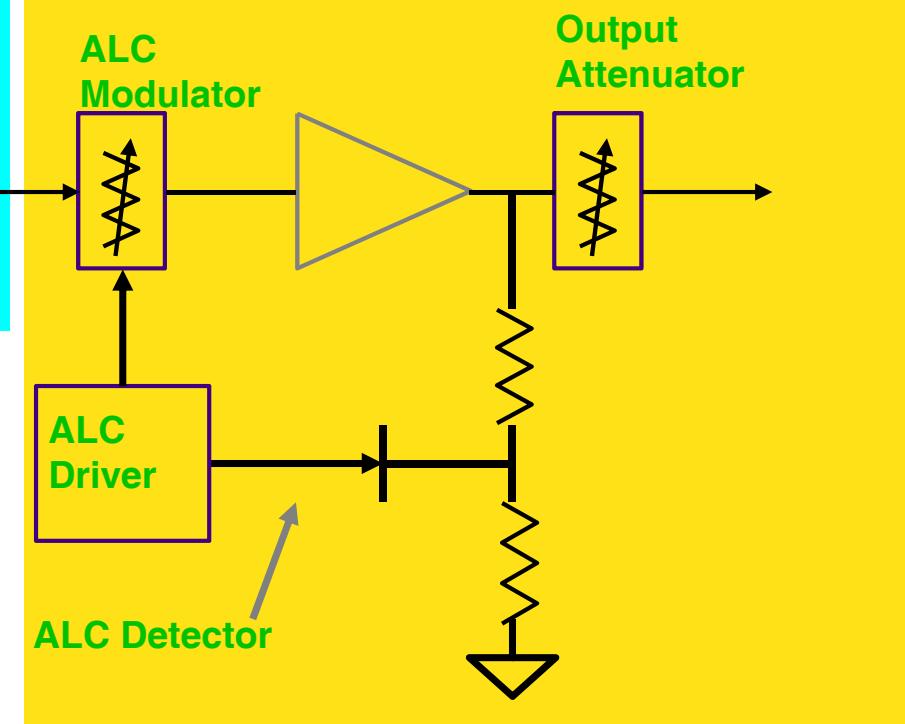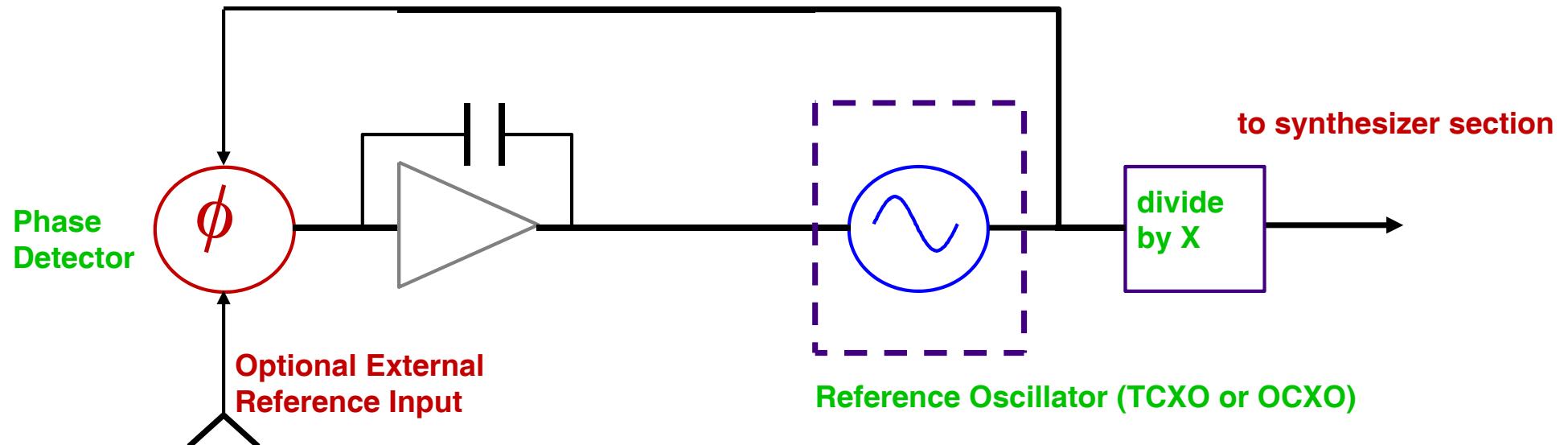
Reference Section

ALC = automatic level control

RF CW block diagram: reference section

Phase Detector

Optional External Reference Input

Reference Oscillator (TCXO or OCXO)

to synthesizer section

divide by X
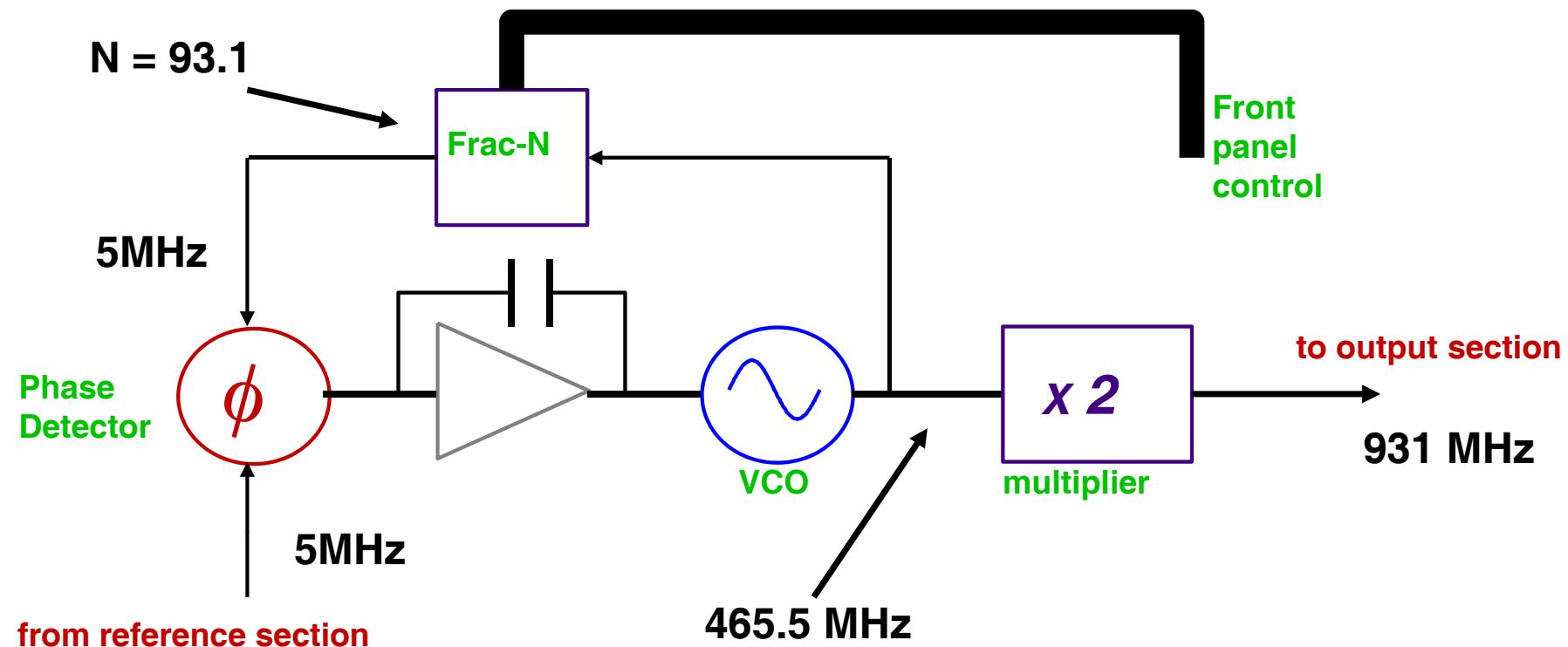
	TCXO	OCXO
Aging Rate	+/- 2ppm/year	+/- 0.1 ppm /year
Temp.	+/- 1ppm	+/- 0.01 ppm
Line Voltage	+/- 0.5ppm	+/- 0.001 ppm
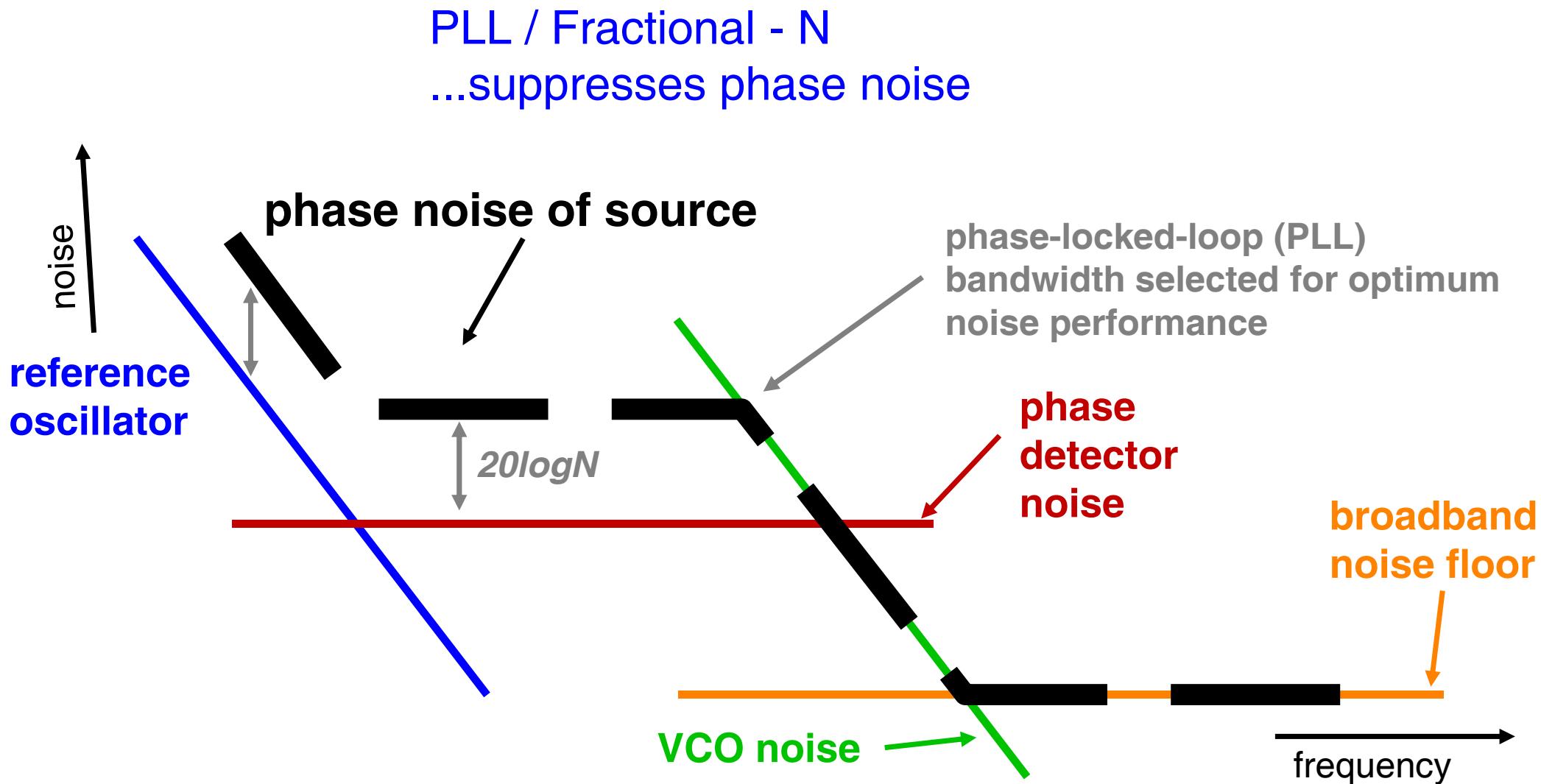
TCXO = Temperature Compensated Crystal Oscillator
OCXO = Oven Controlled Crystal Oscillators

RF CW block diagram: synthesizer section

...produces accurate, clean signals

N = 93.1

Frac-N

5MHz

Front panel control

Phase Detector

φ

5MHz

from reference section

VCO

465.5 MHz

x 2

multiplier

to output section

931 MHz

RF CW block diagram: synthesizer section

PLL / Fractional - N
...suppresses phase noise

noise

phase noise of source

reference oscillator

20logN

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

phase detector noise

broadband noise floor

VCO noise

frequency
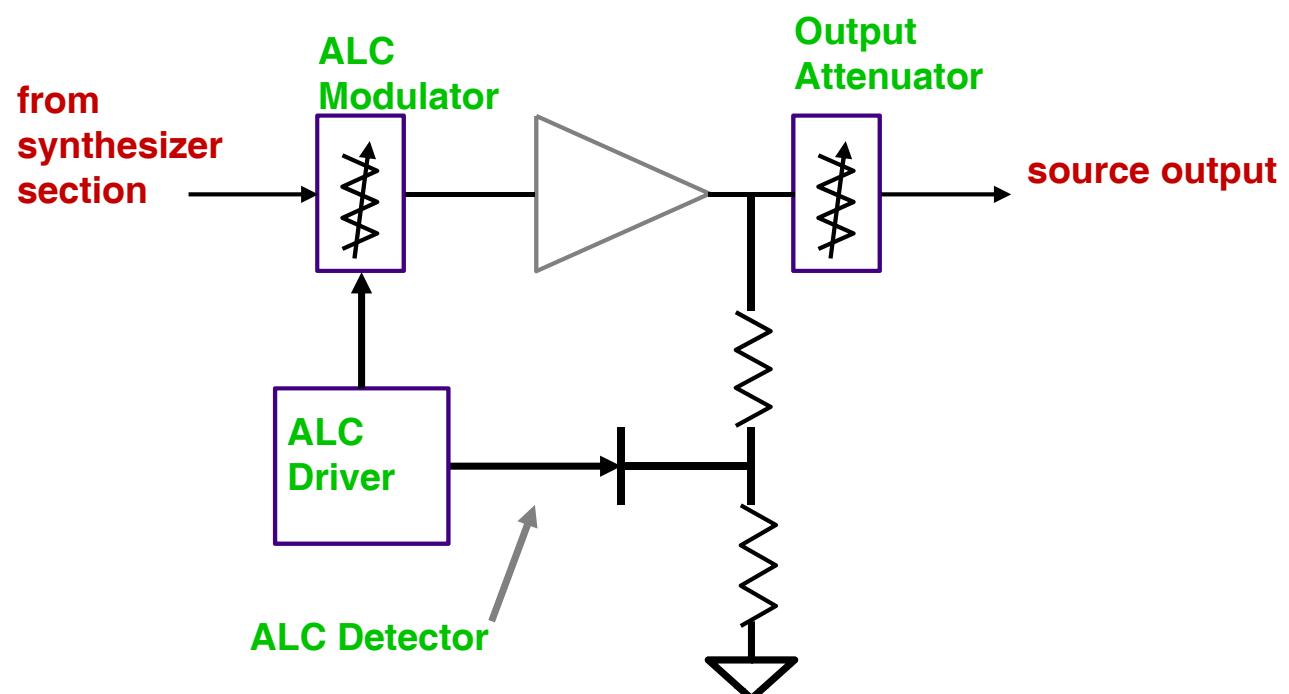
RF CW block diagram: output section

- ALC
  - maintains output power by adding/subtracting power as needed
- Output Attenuator
  - mechanical or electronic
  - provides attentuation to achieve wide output range (e.g. -136dBm to +13dBm)

ALC Modulator

Output Attenuator

from synthesizer section

source output

ALC Driver
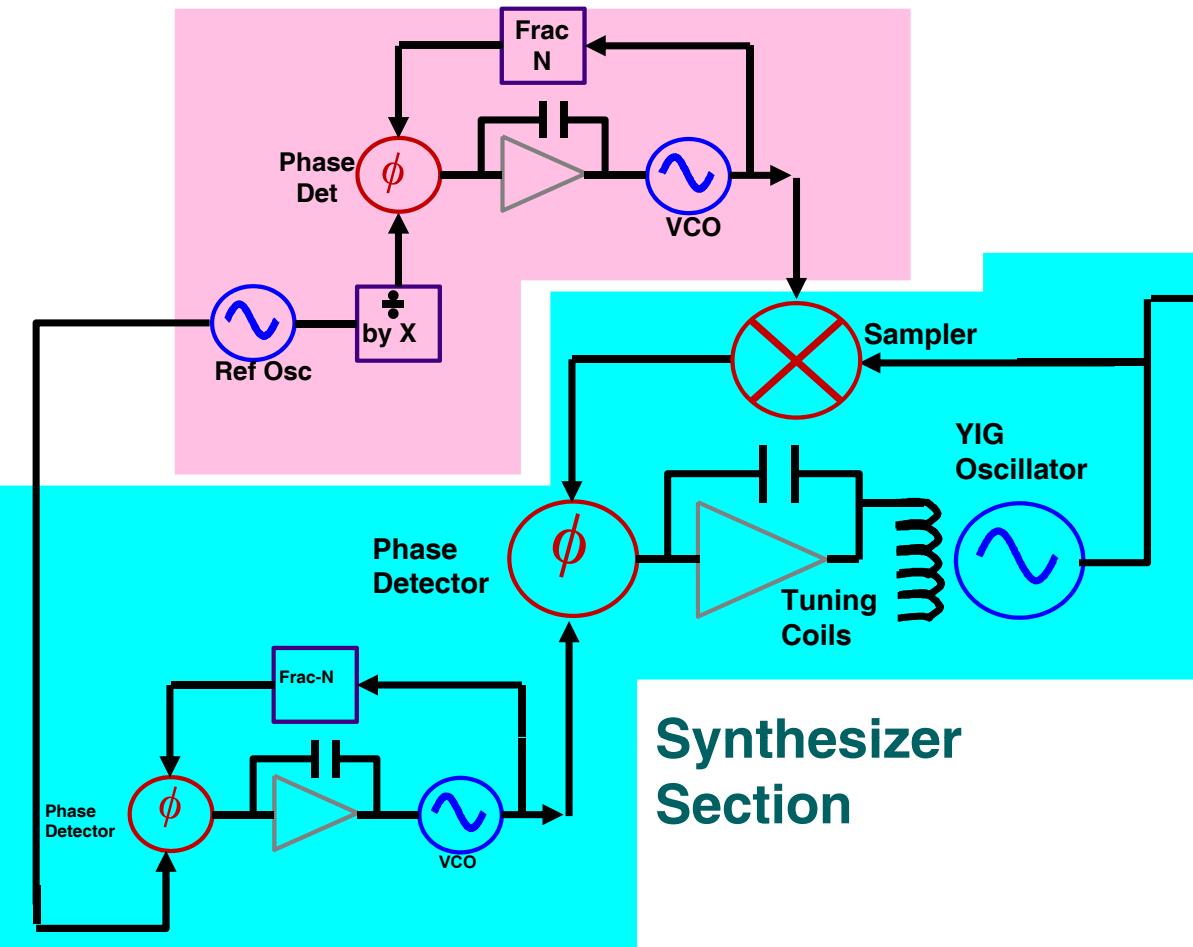
ALC Detector

ALC = automatic level control
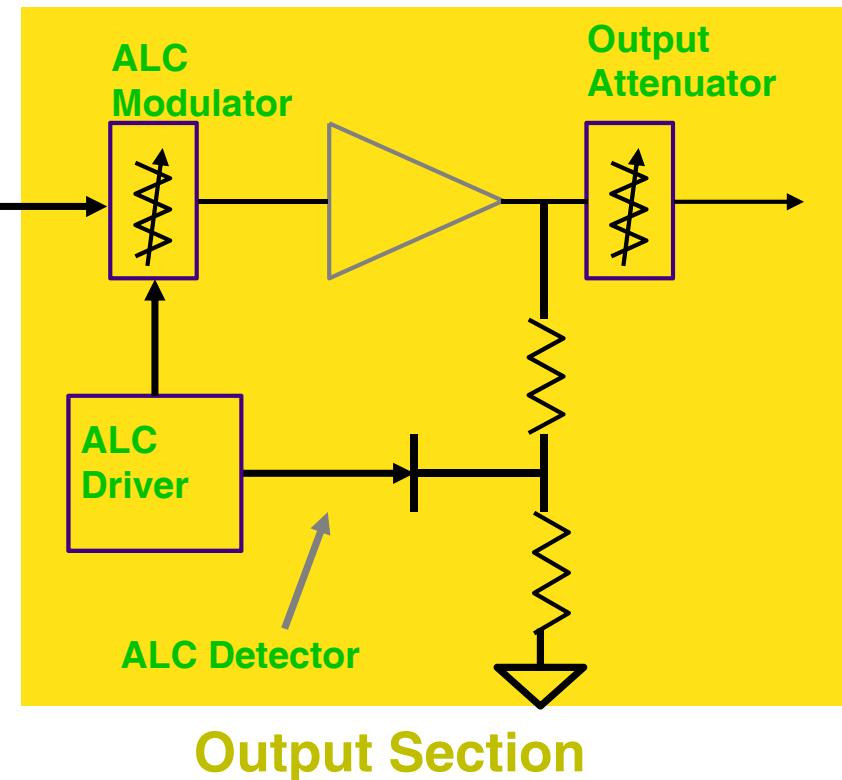
Microwave CW block diagram

Reference Section

Frac N

Phase Det

ϕ

VCO

Ref Osc

÷ by X

Sampler

YIG Oscillator

Phase Detector

ϕ

Tuning Coils

Frac-N

Phase Detector

ϕ

VCO

Synthesizer Section

ALC Modulator

Output Attenuator

ALC Driver

ALC Detector
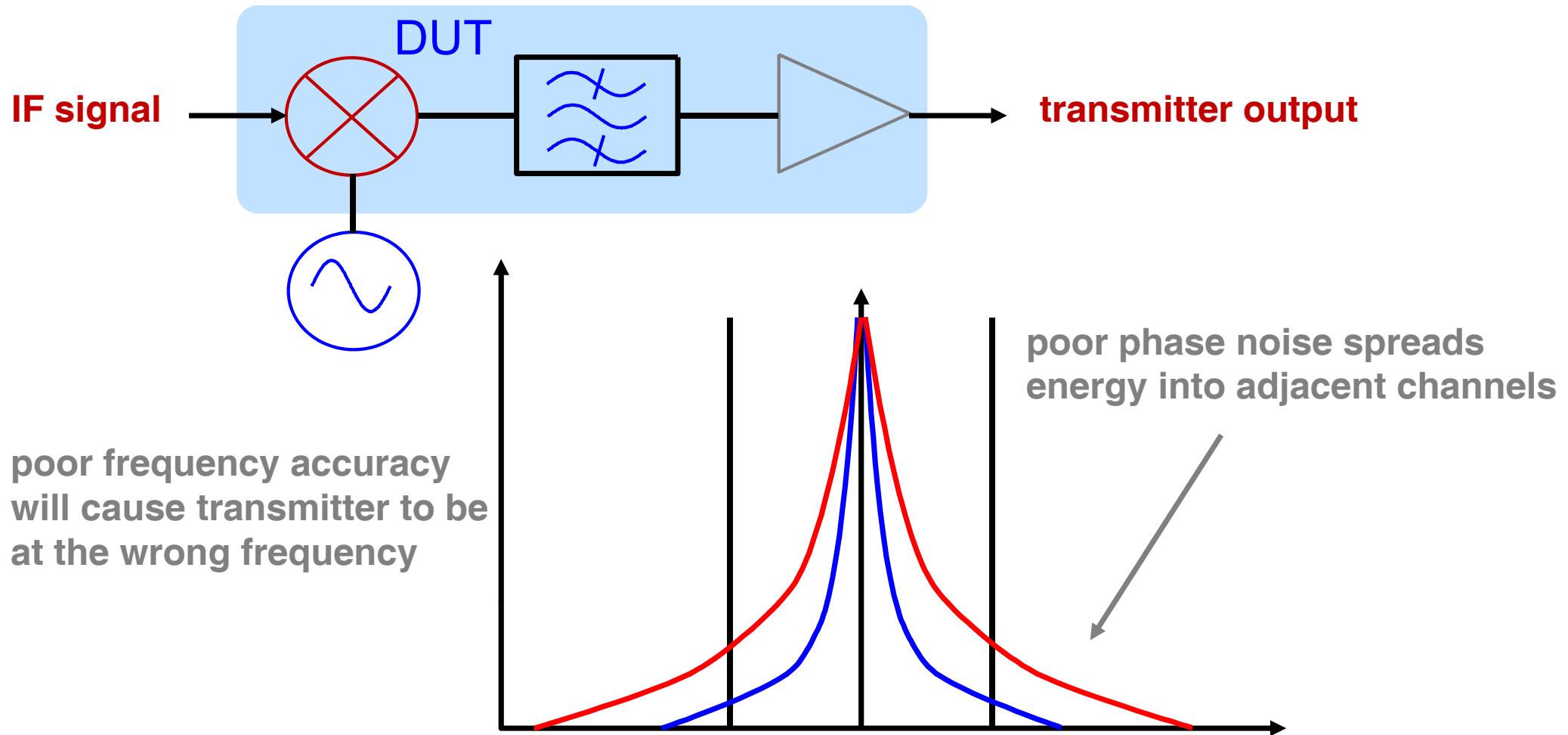
Output Section

CW: Applications & Critical Specifications

- Local Oscillator
  - phase noise
  - frequency accuracy
- Amplifier
  - distortion
  - spurious
- Receiver Testing
  - spurious
  - level accuracy

CW: Applications & Critical Specifications

As a Local Oscillator

IF signal → DUT (mixer × with local oscillator, filter, amplifier) → **transmitter output**

poor phase noise spreads energy into adjacent channels

poor frequency accuracy will cause transmitter to be at the wrong frequency
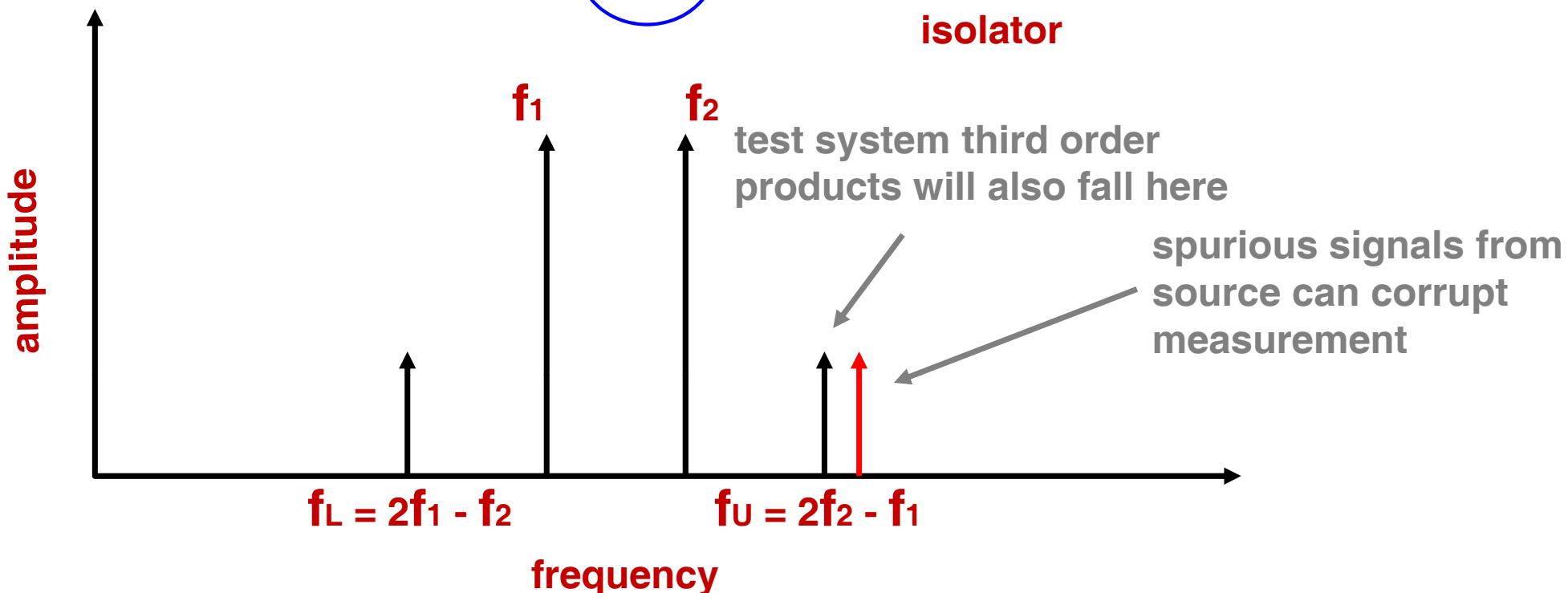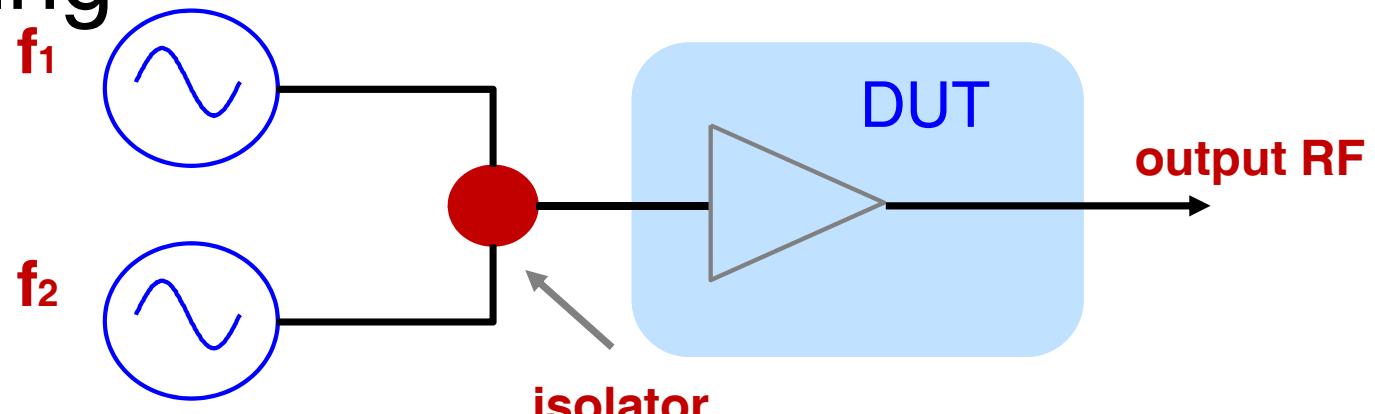
CW: Applications & Critical Specifications

Amplifier Testing
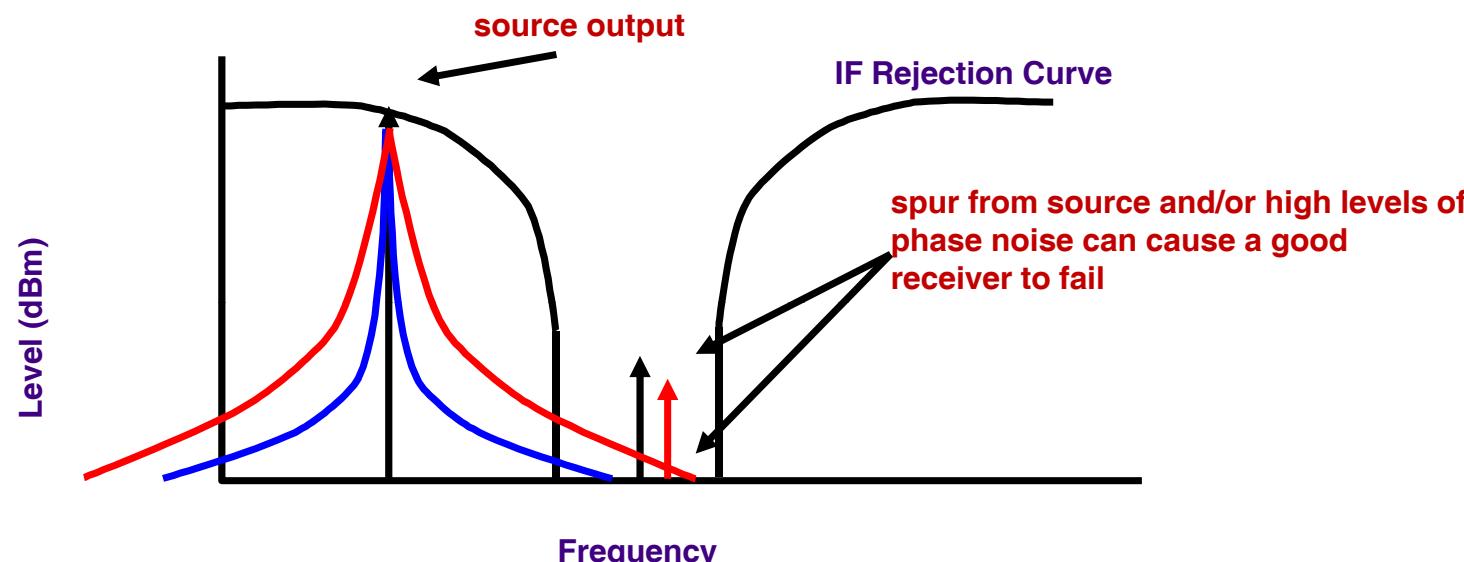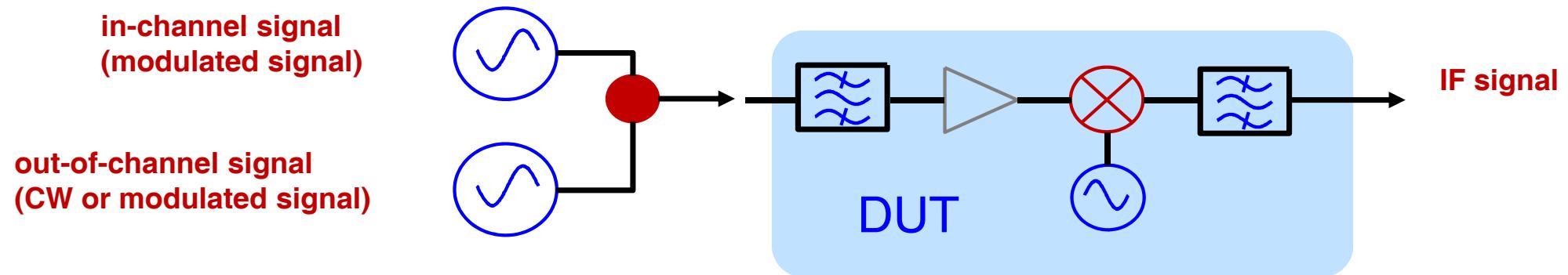
Intermodulation
Distortion

f₁

f₂

DUT

output RF

isolator

f₁

f₂

test system third order
products will also fall here

spurious signals from
source can corrupt
measurement

amplitude

$f_L = 2f_1 - f_2$

$f_U = 2f_2 - f_1$

frequency

CW: Applications & Critical Specifications

Receiver Testing

Receiver Selectivity

in-channel signal (modulated signal)

out-of-channel signal (CW or modulated signal)

DUT

IF signal

source output

IF Rejection Curve

spur from source and/or high levels of phase noise can cause a good receiver to fail

Level (dBm)

Frequency

Examples: Agilent CW Generators

RF

Agilent 8662/63 family
- 100 KHz - 2.5 GHz
- Low in channel noise
- AM/FM/Phase/Pulse

Agilent 8664/65 family
- 100 MHz - 6 GHz
- Low out channel noise
- AM/FM/Pulse.

Microwave
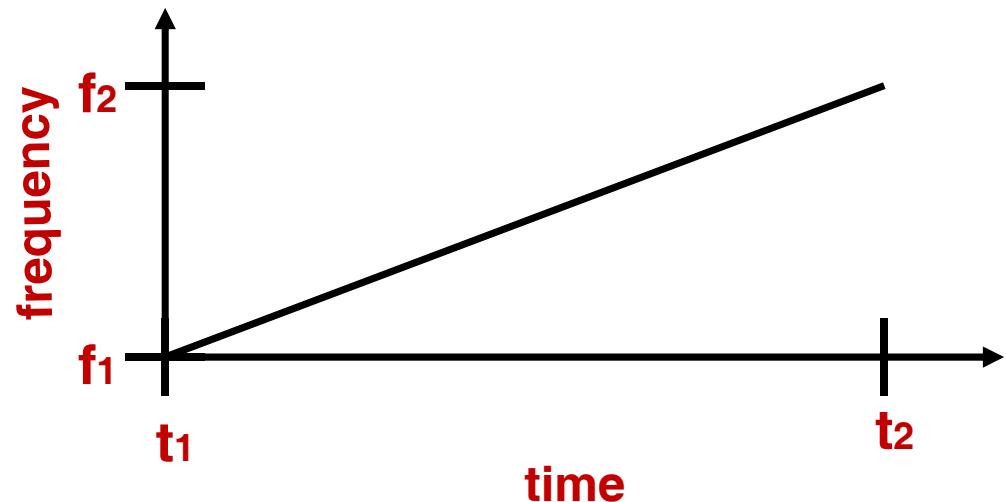
Agilent 83711/12B family
- 10 MHz - 20 GHz
- CW only

Sweeper specifications: frequency
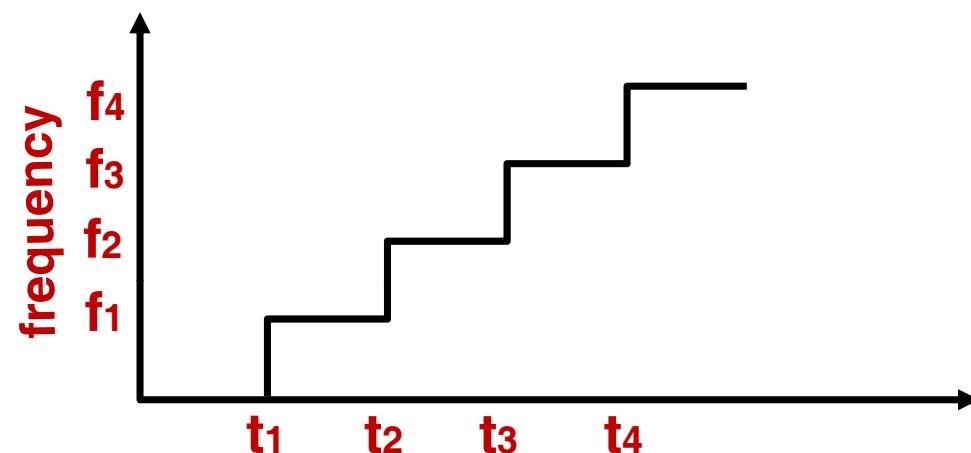
- **ramp sweep**
  - accuracy
  - sweep time
  - resolution
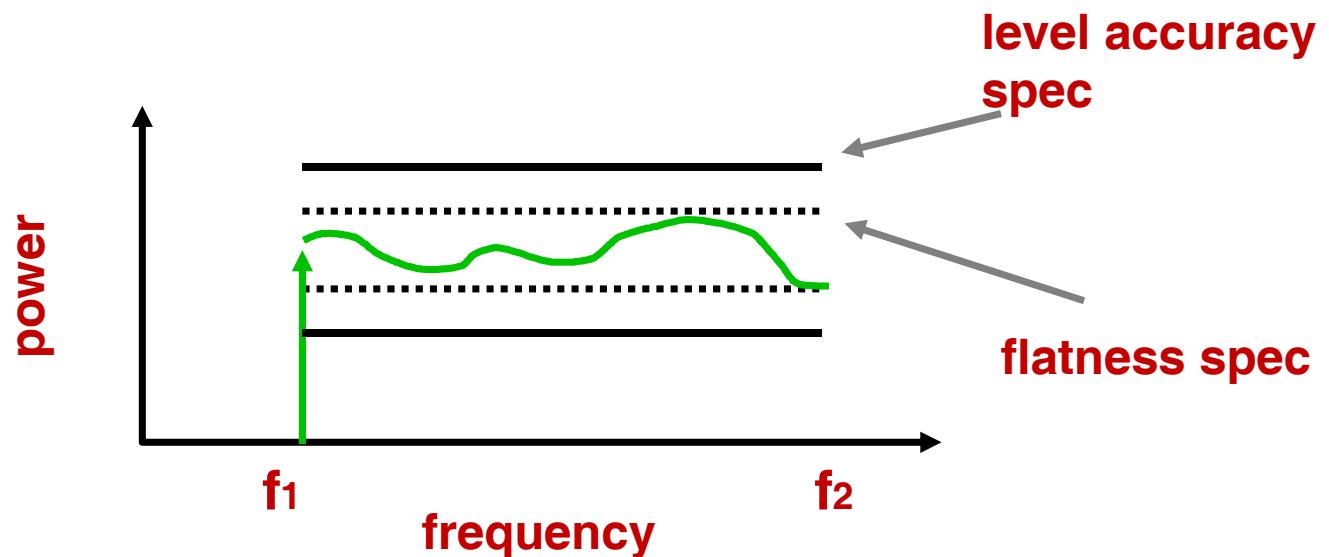
- **step sweep**
  - accuracy
  - number of points
  - switching time

Sweeper specifications: amplitude
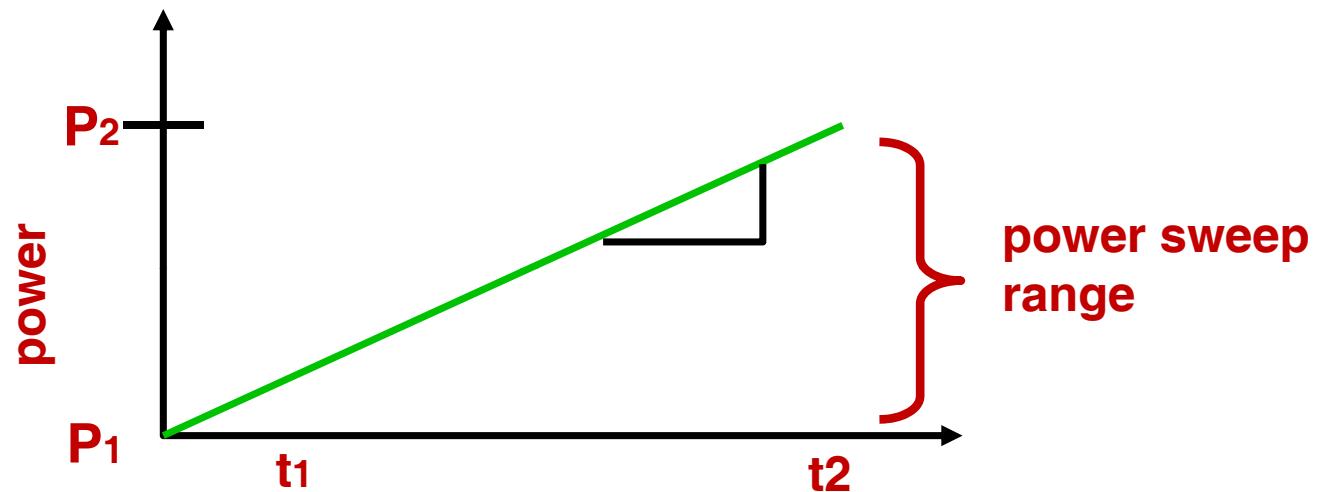
Frequency Sweep
- Level Accuracy
- Flatness
- Source Match (SWR)

level accuracy spec

flatness spec

power

f_1 f_2

frequency

Power Sweep
- Power Sweep Range
- Power Slope Range
- Source Match (SWR)

P_2

P_1

power

power sweep range

t_1 t_2

Sweeper: Applications & Critical Specs

- **Frequency Response**
  - Frequency Accuracy
  - Output Power (Level) Accuracy
  - Flatness
  - Speed
  - residual FM
- **Amplifier Compression**
  - Power Range

Frequency Response Testing
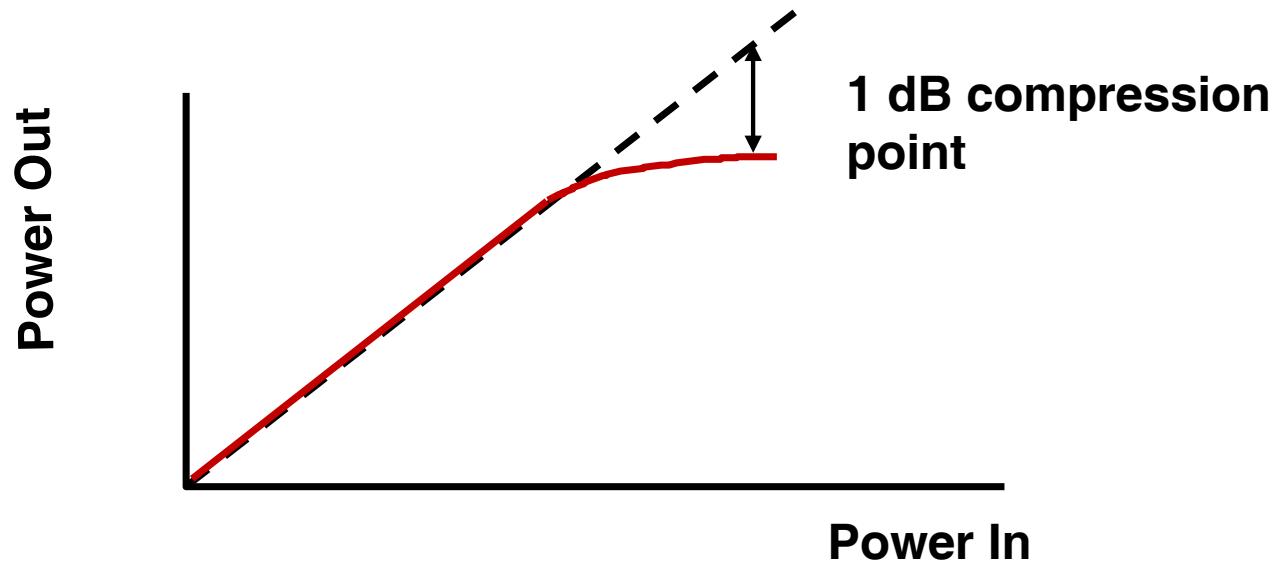
Who Cares About Accuracy?

Sweeper: Applications & Critical Specs

Amplifier Compression

- Power Range

The 1 dB compression point is a common amplifier specification used to identify the linear operating range of an amplifier. Power sweep is available on some sources.

Examples: Agilent Sweep Generators

* **Agilent 83750 Series**
  * Step/Analog sweep
  * AM/FM/Phase modulation
  * 10MHz to 20GHz
  * up to 110GHz with 83550 series
  * modules and amplifier

HP 83732B/HP 83731B 1 GHz to 20 GHz synthesized signal generator

* **Agilent 8360L Series**
  * Step/Analog sweep
  * 8510/8757 Compatibility
  * 10MHz to 50GHz
  * up to 110GHz with 83550 series modules

HP 8360B/L series synthesized swept-CW and swept-signal generator

Signal generators
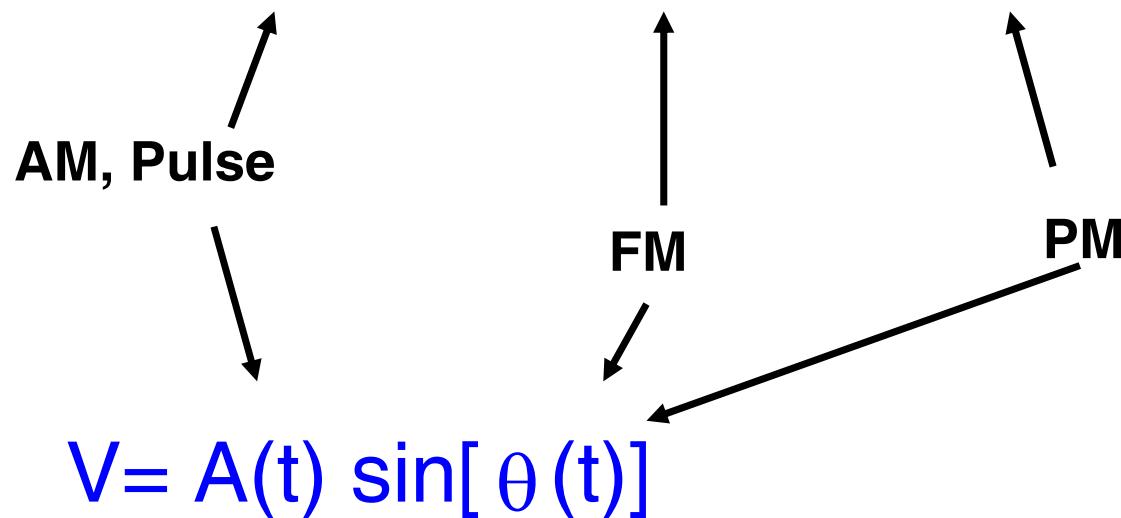
- Calibrated modulation
    - Analog (AM, FM, PM, Pulse)
    - Digital (I-Q)
    - Format Specific(TDMA,CDMA, etc.)

Modulation
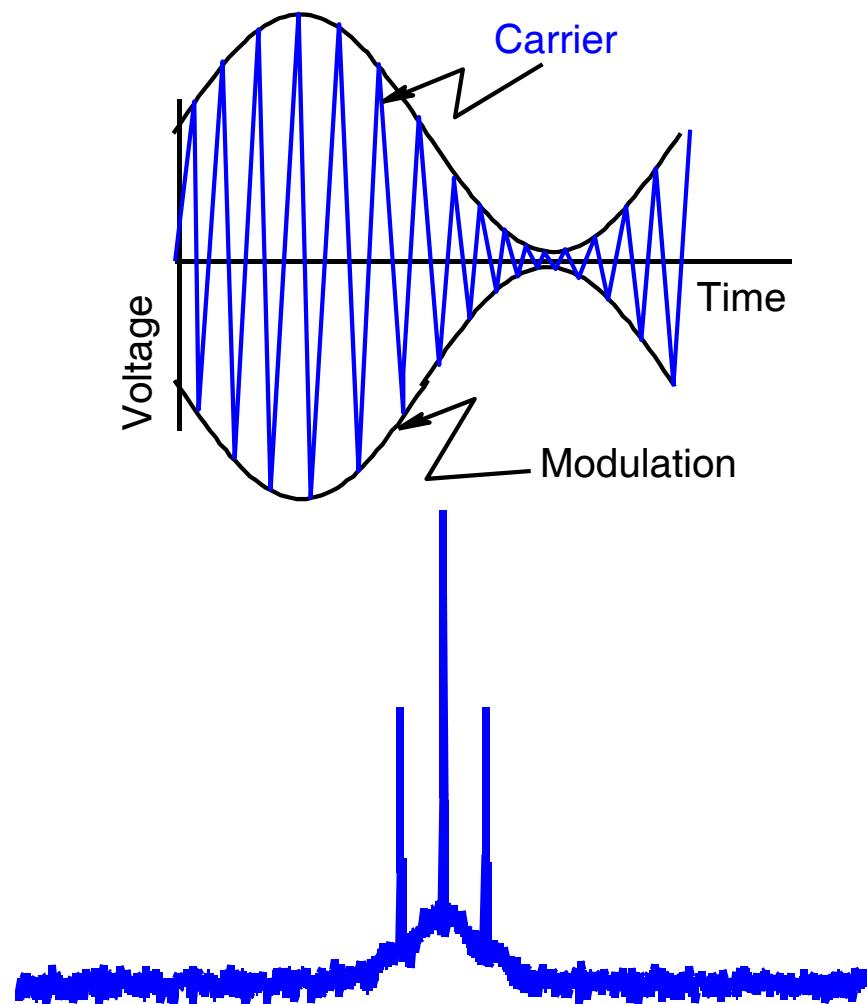
...Where the information resides

$$V = A(t) \sin[2\pi f(t) + \phi(t)]$$

AM, Pulse

FM   **PM**

$$V = A(t) \sin[\theta(t)]$$

Modulation: analog

Amplitude Modulation

Carrier

Voltage

Time

Modulation

Important Signal Generator Specs for
Amplitude Modulation
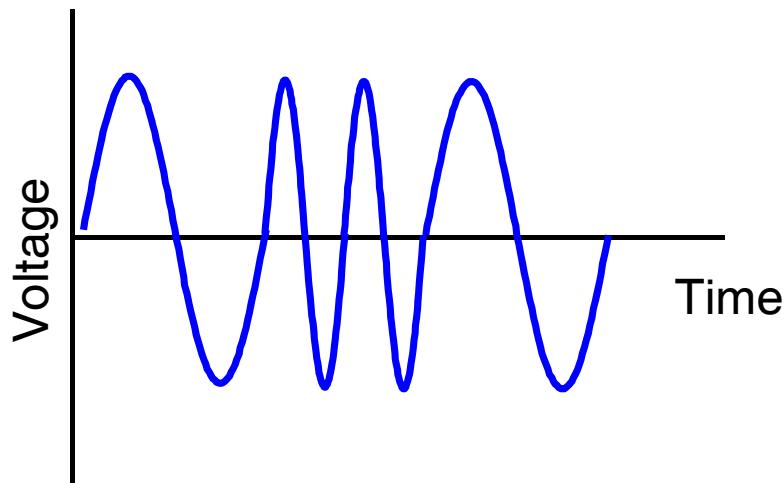
- Modulation frequency
- Linear AM
- Log AM
- Depth of modulation (Mod Index)

Modulation: analog

Frequency Modulation

$$V = A \sin[2\pi f_c t + \beta\, m(t)]$$

$$\beta = \Delta F_{dev}/F_{mod}$$

Important Signal Generator Specs for Frequency Modulation
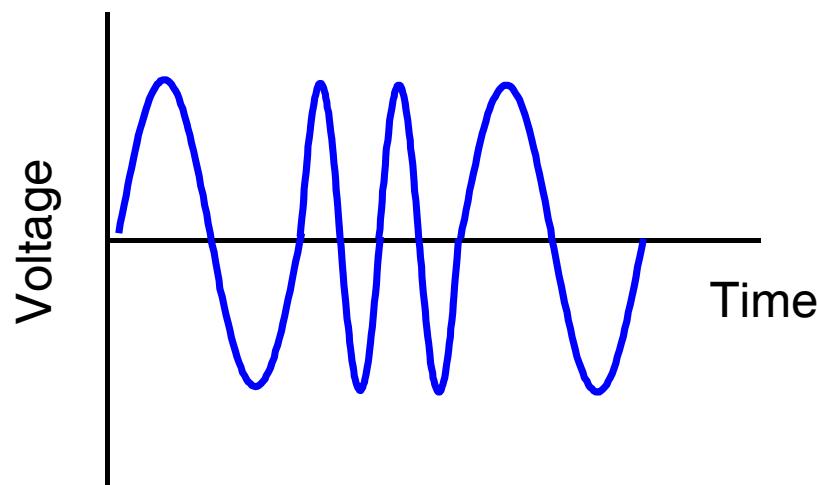
- Frequency Deviation
- Modulation Frequency
- dcFM
- Accuracy
- Resolution

Modulation: analog

Phase Modulation

$$V = A \sin[2\pi f_c t + \beta m(t)]$$

$$\beta = \Delta\phi_{peak}$$
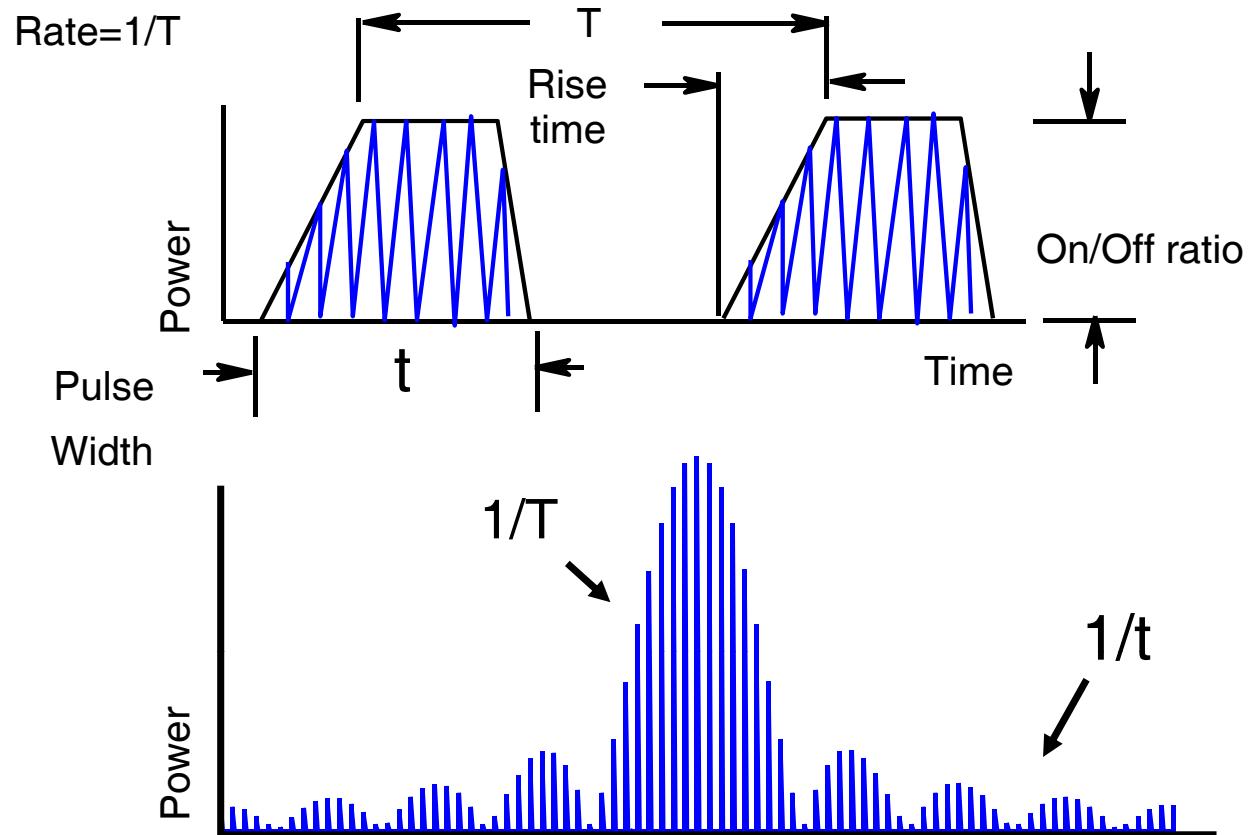
Important Signal Generator Specs for Phase Modulation

- Phase deviation
- Rates
- Accuracy
- Resolution

Modulation: analog

Pulse Modulation
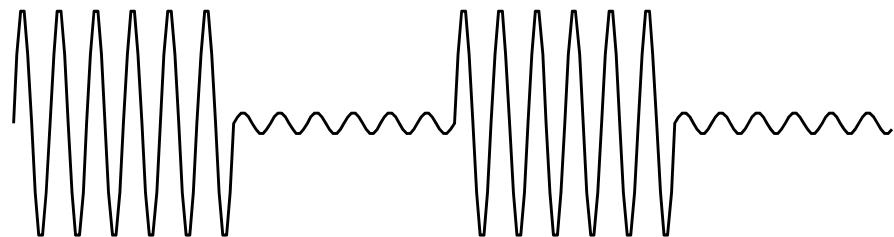
Important Signal Generator Specs for Pulse Modulation

- Pulse width
- Pulse period
- On/Off ratio
- Rise time
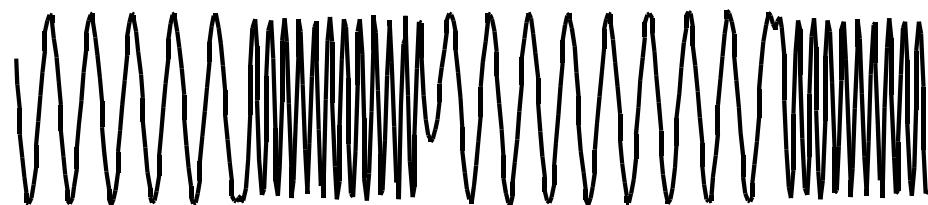
Modulation: digital

...signal characteristics to modify
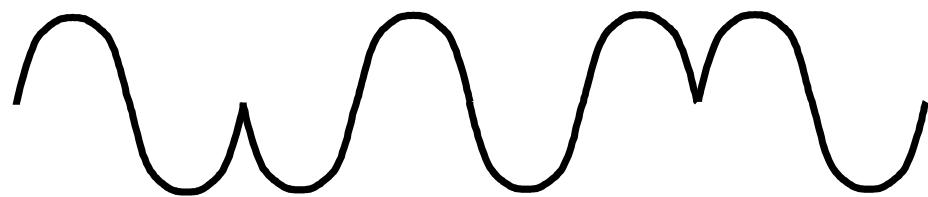
Amplitude
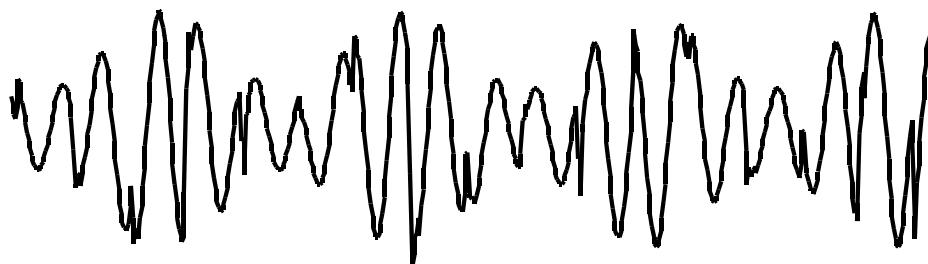
Frequency

Phase
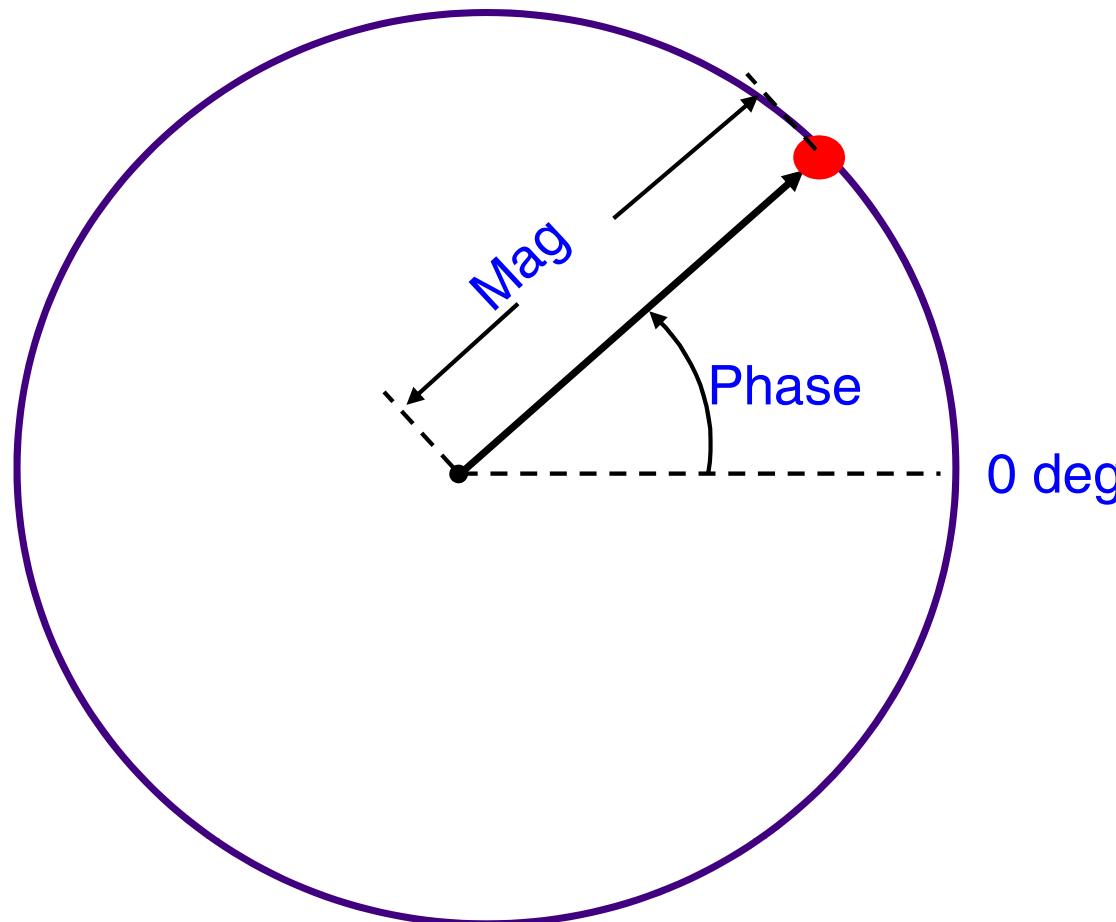
Both Amplitude
and Phase

Modulation: digital
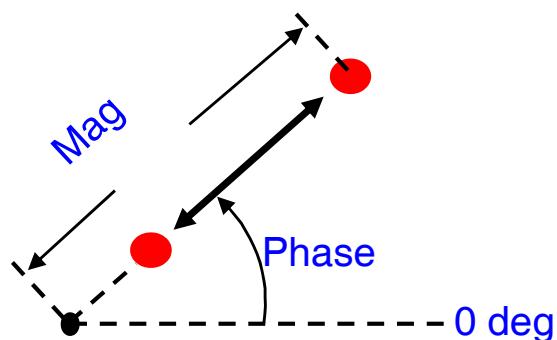
Polar Display: Magnitude & Phase Represented Together
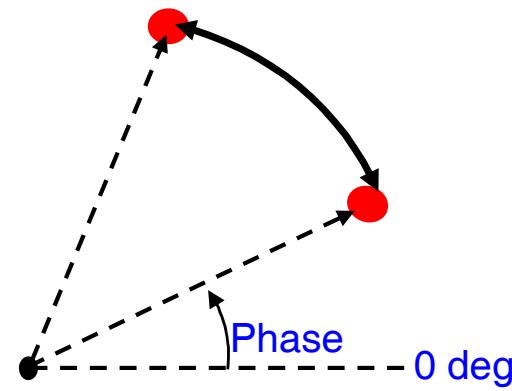
- Magnitude is an absolute value
- Phase is relative to a reference signal

Modulation: digital
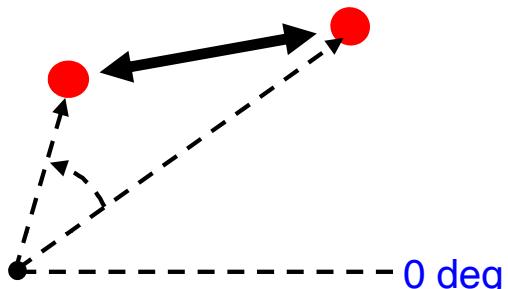
Signal Changes or Modifications
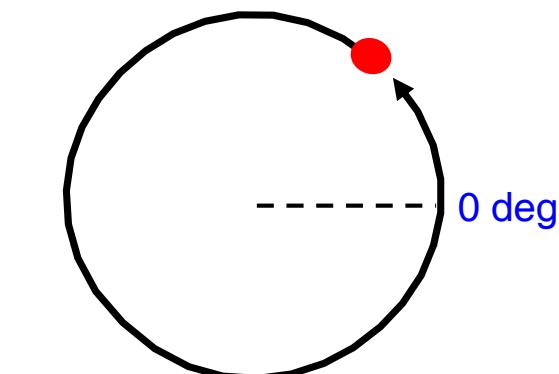
Magnitude Change


Phase Change
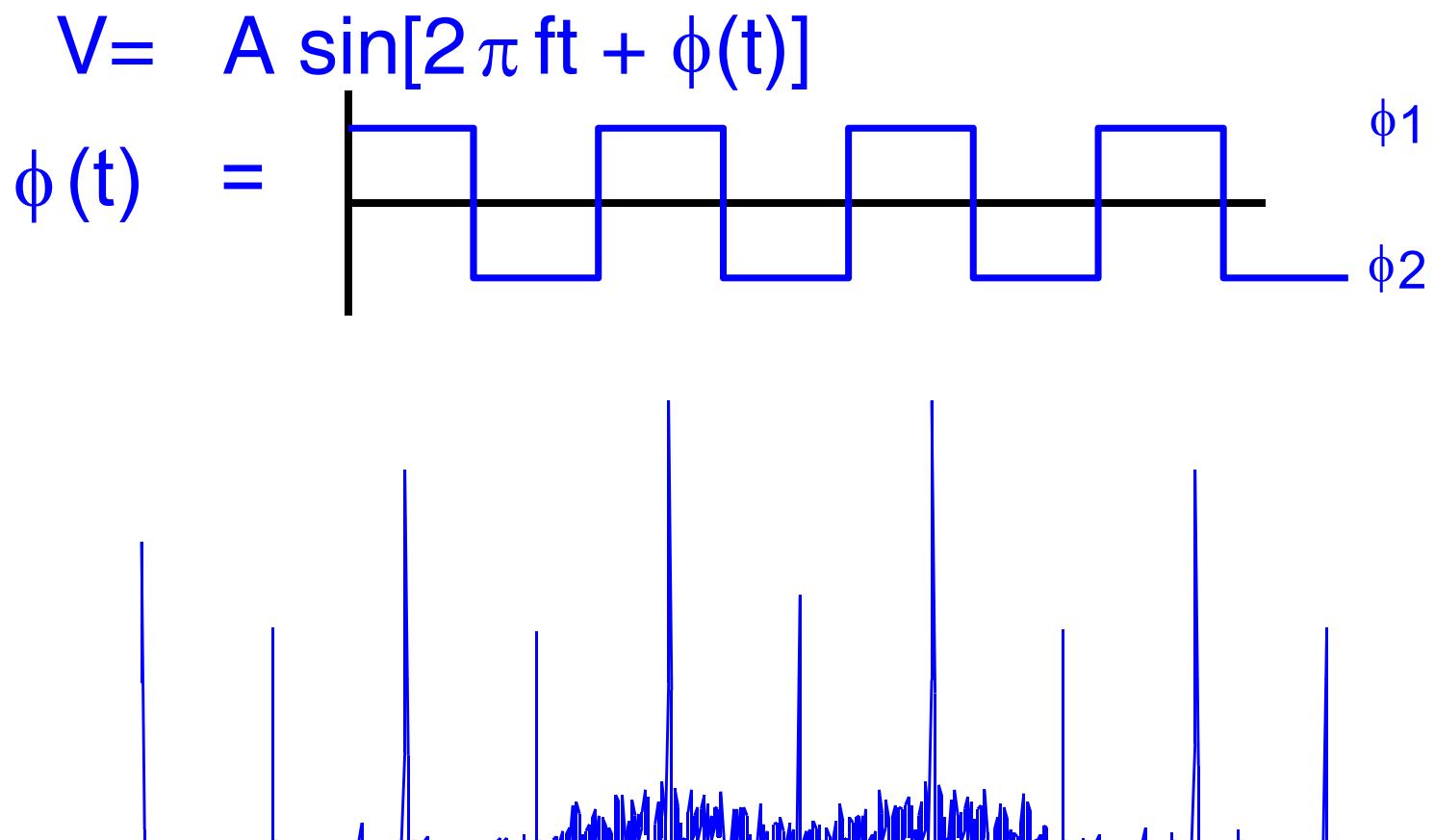
Both Change

Frequency Change
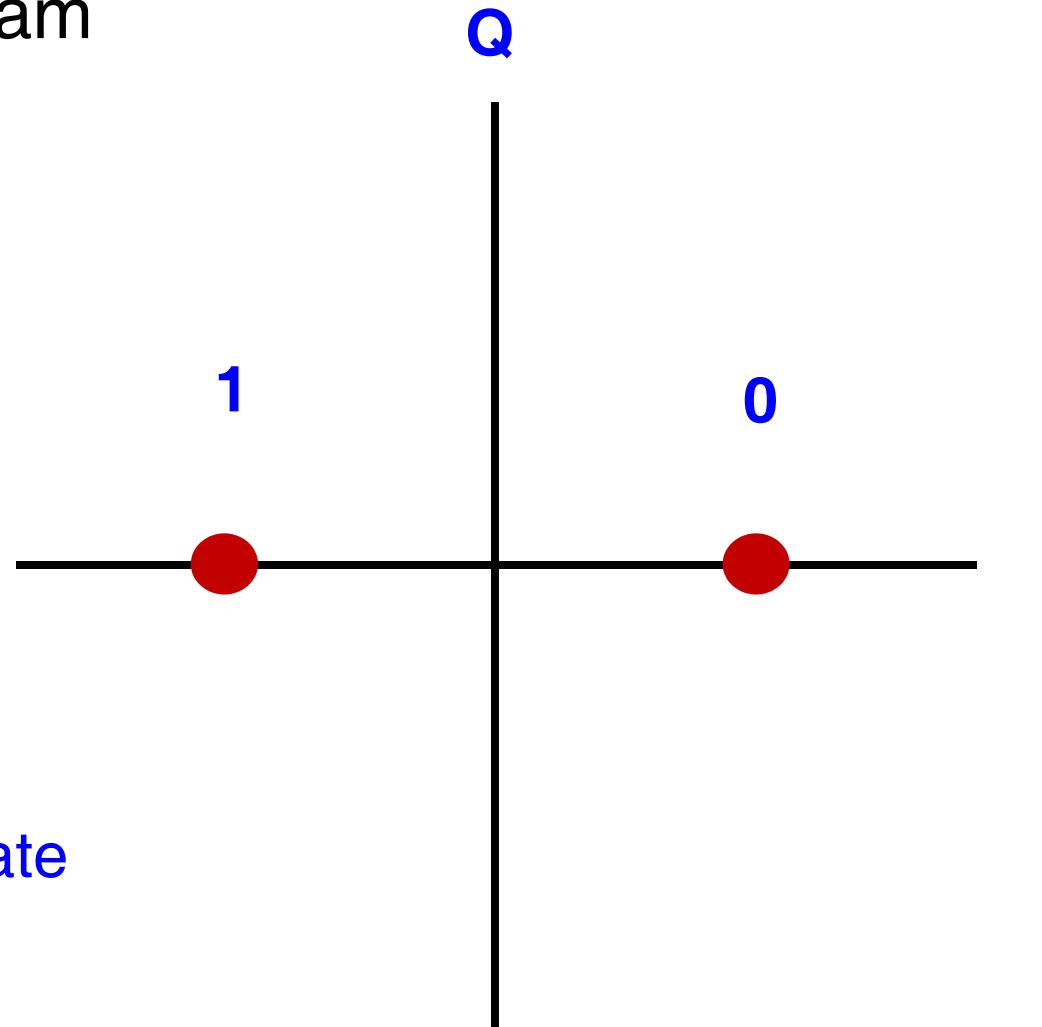
Modulation: digital

...Binary Phase Shift Keying (BPSK)

$$V = A \sin[2\pi ft + \phi(t)]$$

$$\phi(t) =$$

Modulation: digital

BPSK IQ Diagram

Q

1   0

I
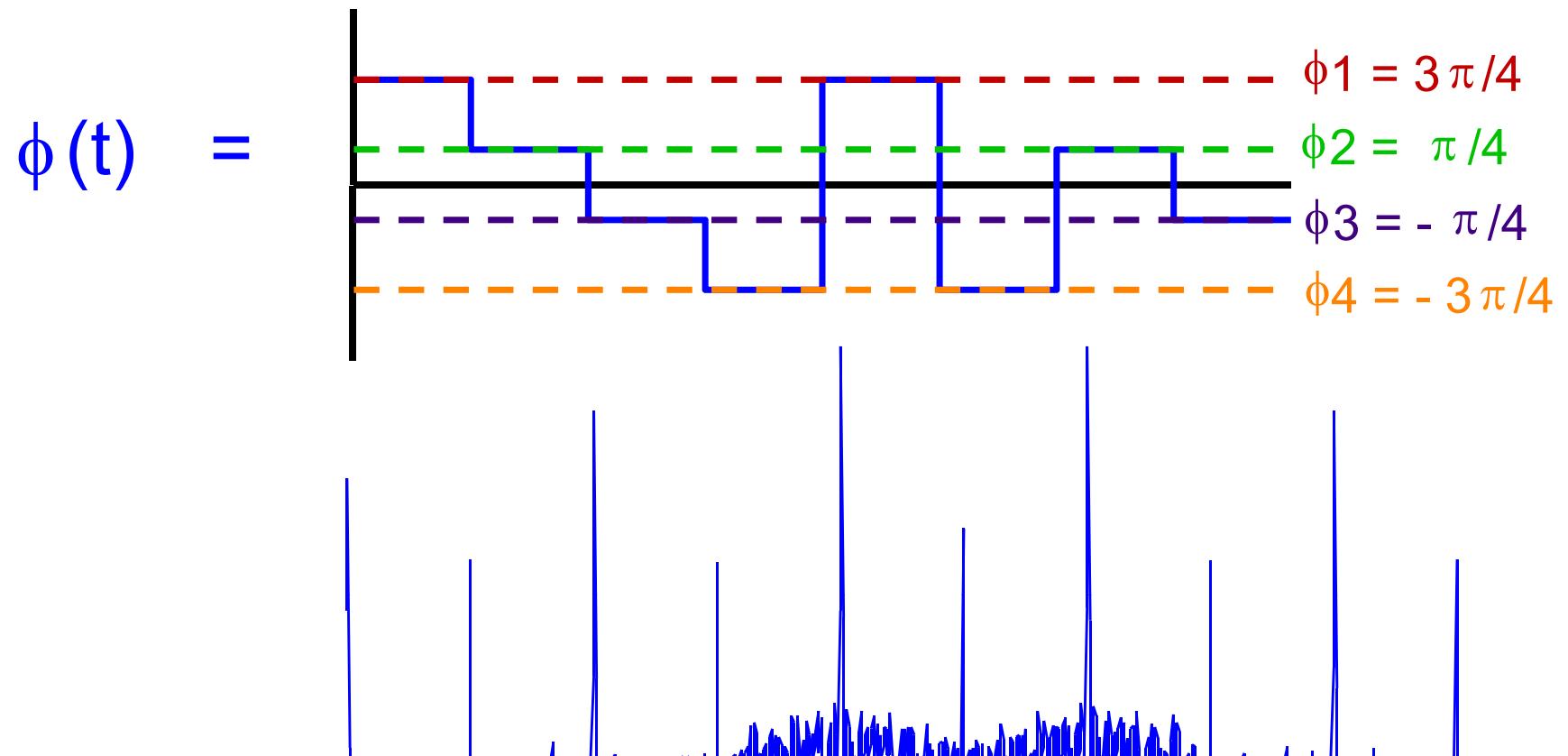
One Bit Per Symbol
Symbol Rate = Bit Rate

Modulation: digital
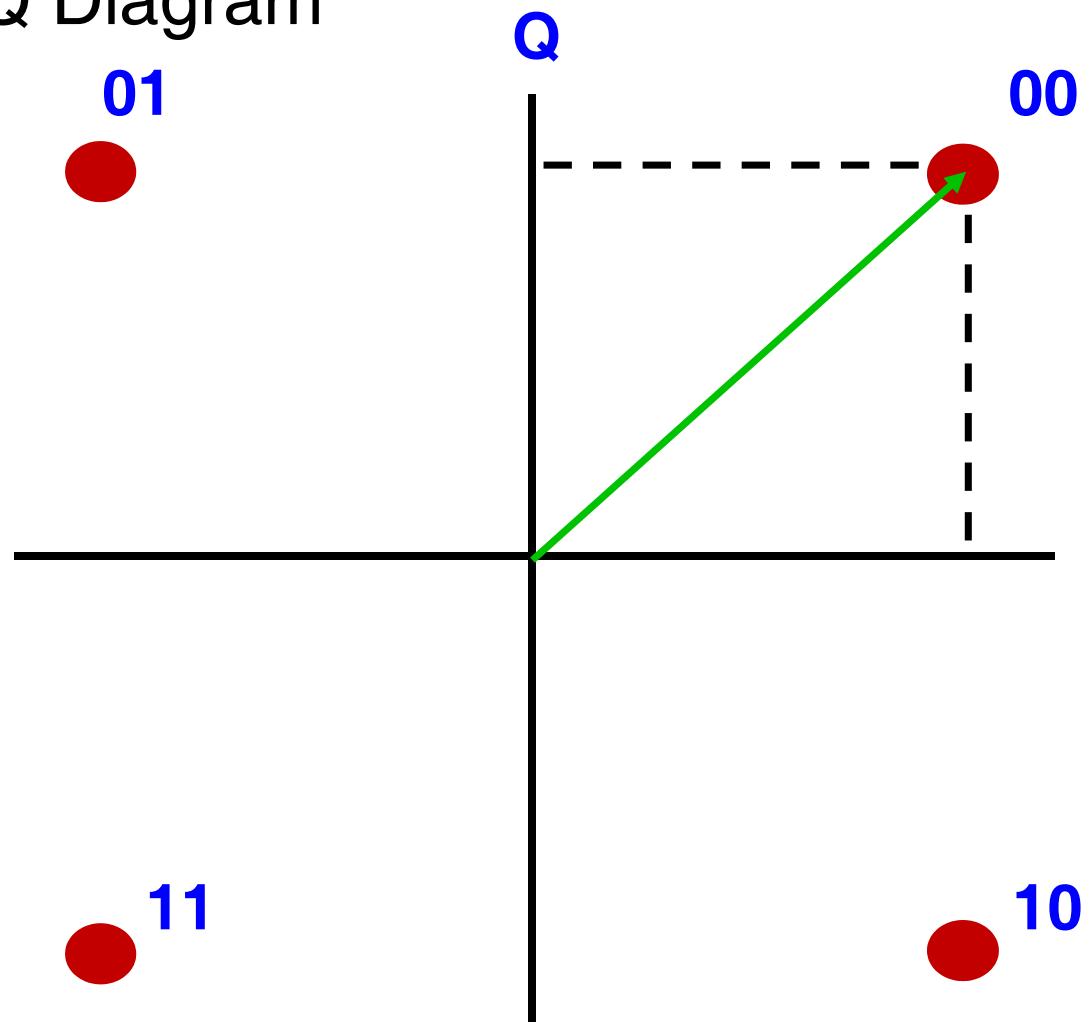
...Quadrature Phase Shift Keying (QPSK)

$$V = A \sin[2\pi ft + \phi(t)]$$

$$\phi(t) =$$

$\phi 1 = 3\pi/4$

$\phi 2 = \pi/4$

$\phi 3 = -\pi/4$

$\phi 4 = -3\pi/4$
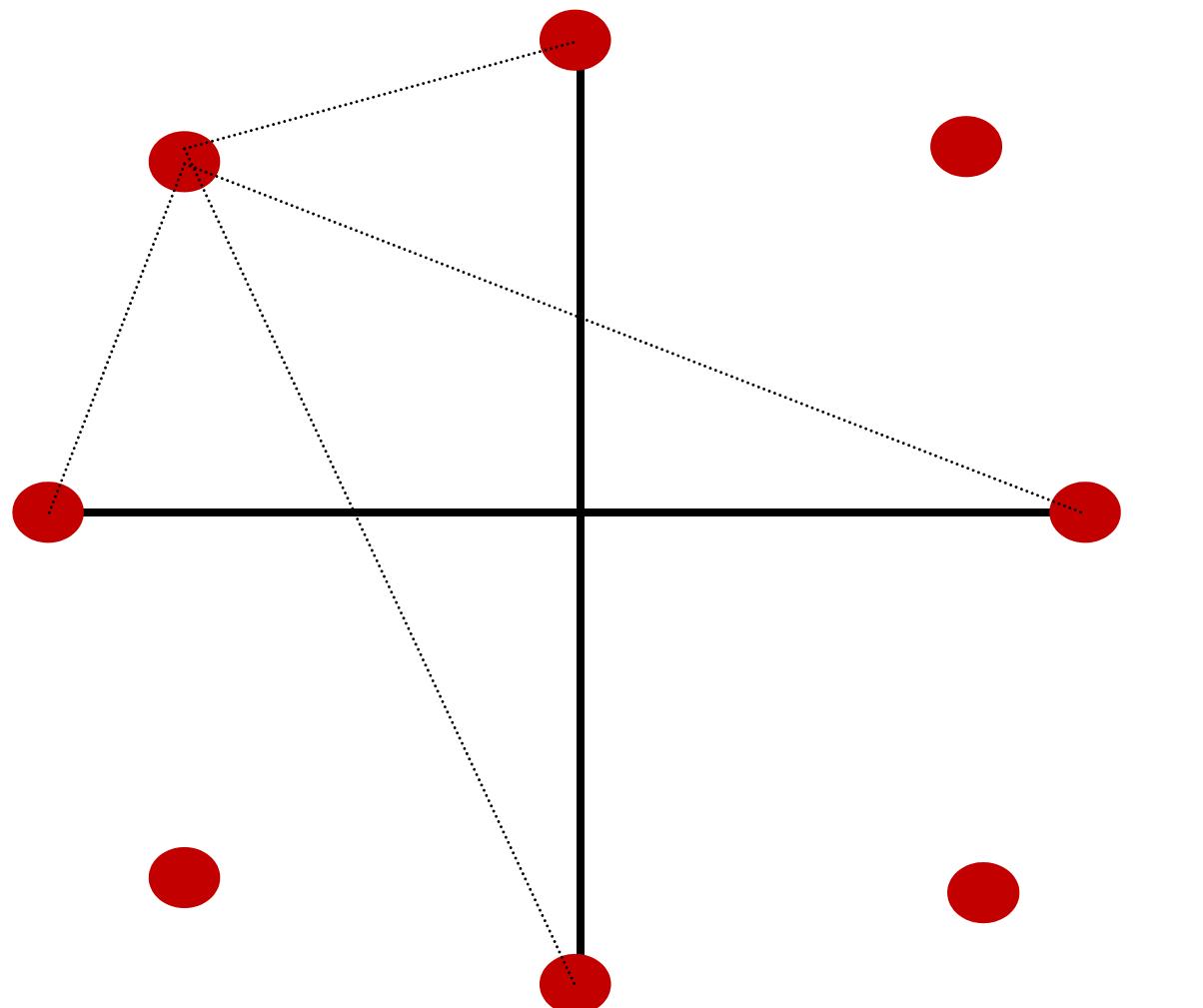
Modulation: digital

QPSK IQ Diagram
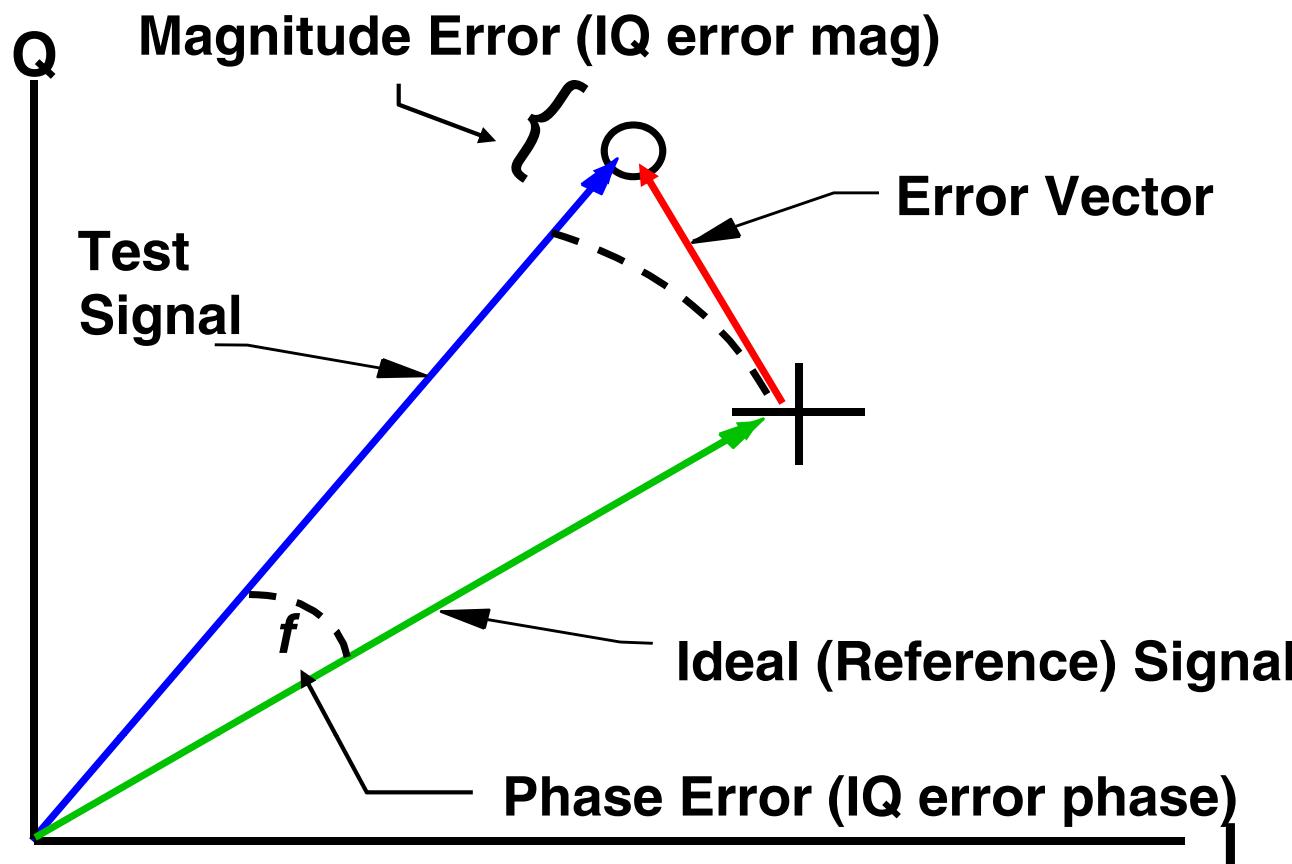
Modulation: digital

$\pi/4$ DQPSK   IQ Diagram   **Q**

I

Modulation: digital

Modulation Accuracy

# Signal generators: Apps & Critical Specs

Analog and Digital

- **Receiver Sensitivity**
  - frequency accuracy
  - level accuracy
  - error vector magnitude

- **Receiver Selectivity**
  - phase noise
  - spurious
  - spectral accuracy
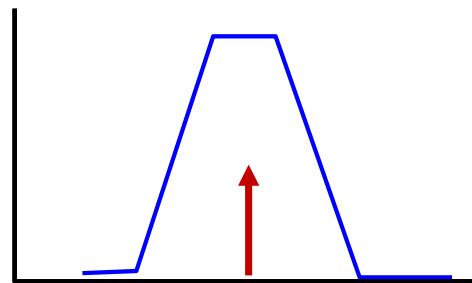
- **Spectral Regrowth**
  - ACP performance
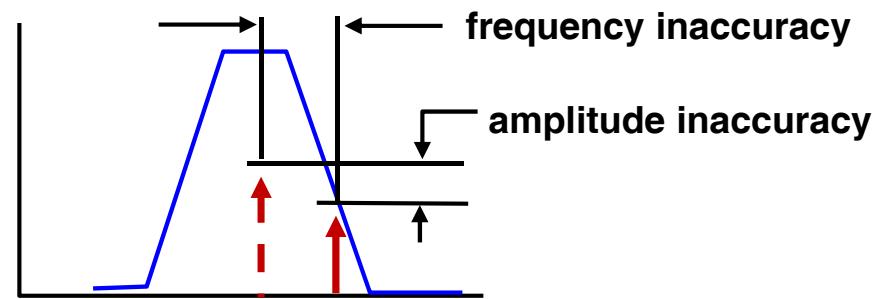
# Signal generators: Apps & Critical Specs

Receiver Sensitivity
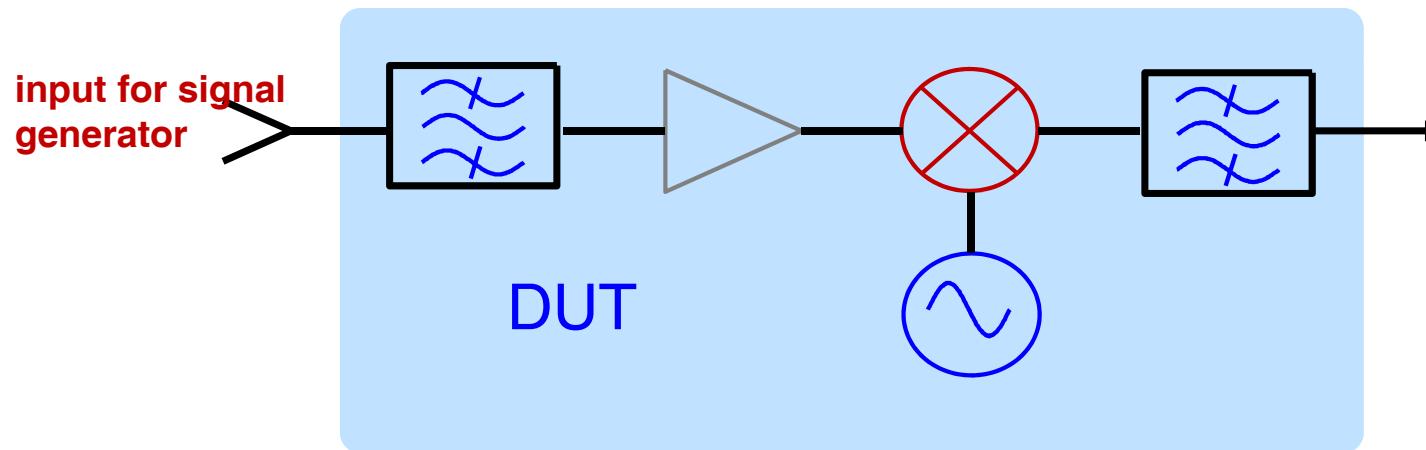
- **Frequency Accuracy**

Want to measure sensitivity in a channel

frequency inaccuracy

amplitude inaccuracy

Measurement impaired by frequency inaccuracy

input for signal generator

DUT

# Signal generators: Apps & Critical Specs

## Receiver Sensitivity

- Level Accuracy
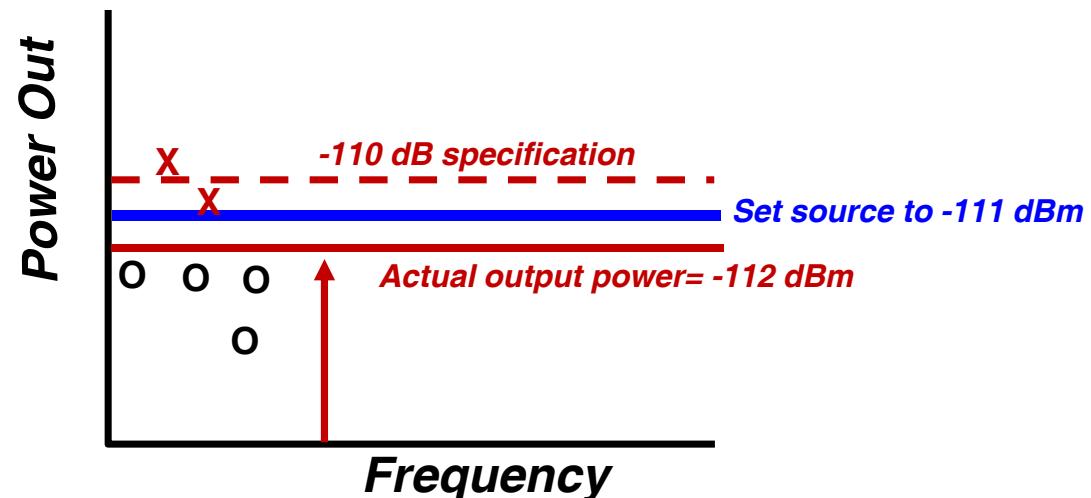
Customer is testing a -110 dB sensitivity pager:

X= Failed unit
O=Passed unit

Case 1: Source has +/-5 dB of output power accuracy at -100 to -120 dBm output power.
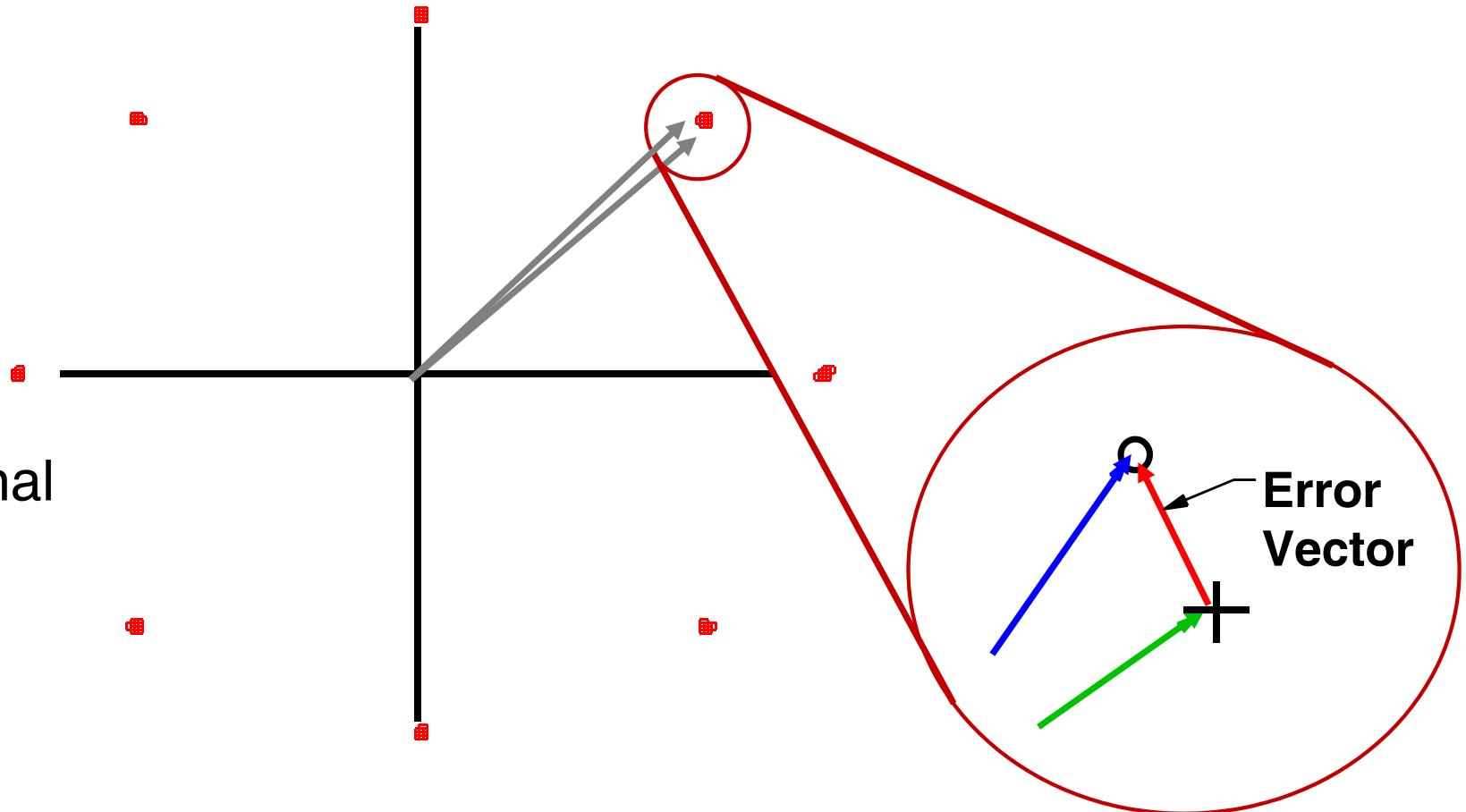
Case 2: Source has +/-1 dB of output power accuracy at -100 to -120 dBm output power.

Signal generators: Apps & Critical Specs

Receiver Sensitivity

- Error Vector Magnitude (EVM)
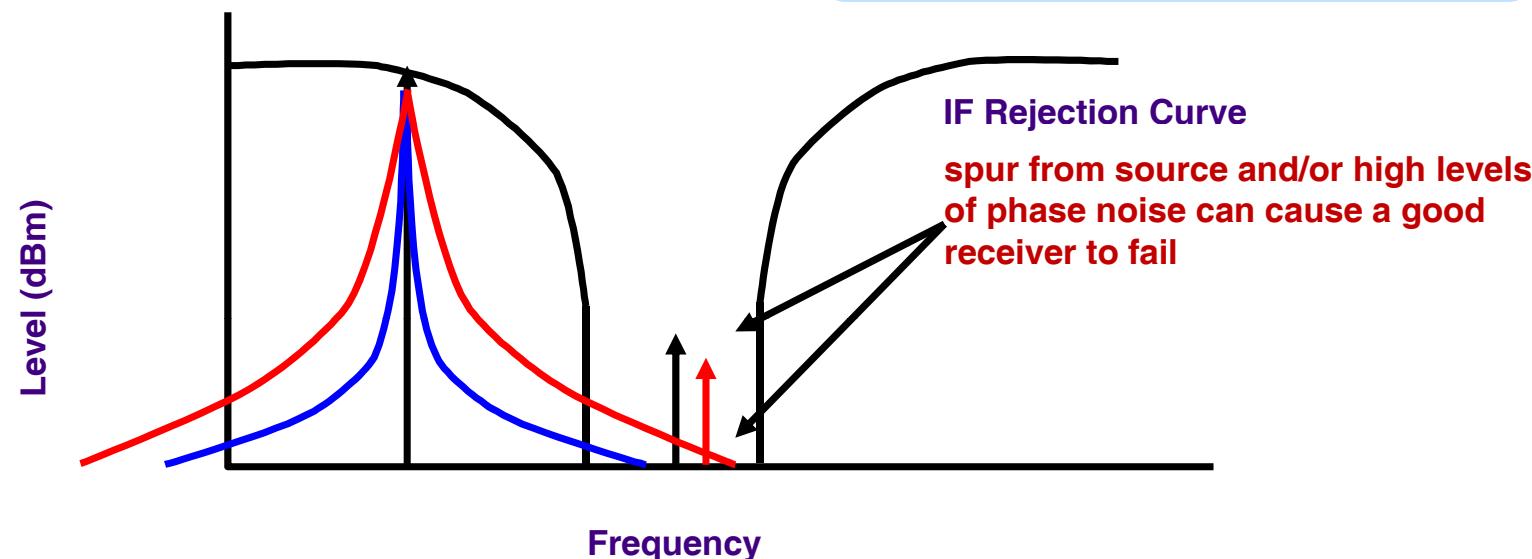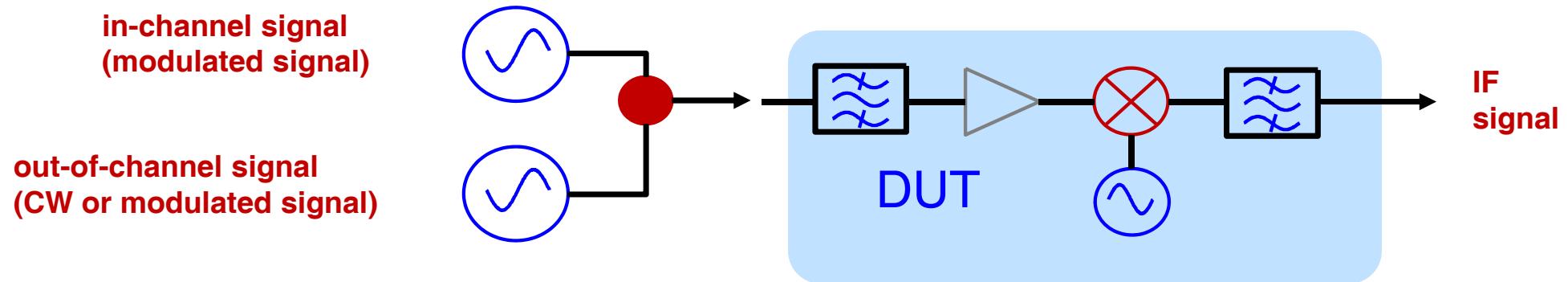
e.g. TETRA Signal
$\pi/4$ DQPSK
EVM < 1.0%

Error Vector

Signal generators: Apps & Critical Specs

Receiver Selectivity
- Phase Noise
- Spurious

**in-channel signal
(modulated signal)**

**out-of-channel signal
(CW or modulated signal)**

DUT

IF
signal

Level (dBm)

IF Rejection Curve

**spur from source and/or high levels
of phase noise can cause a good
receiver to fail**

Frequency
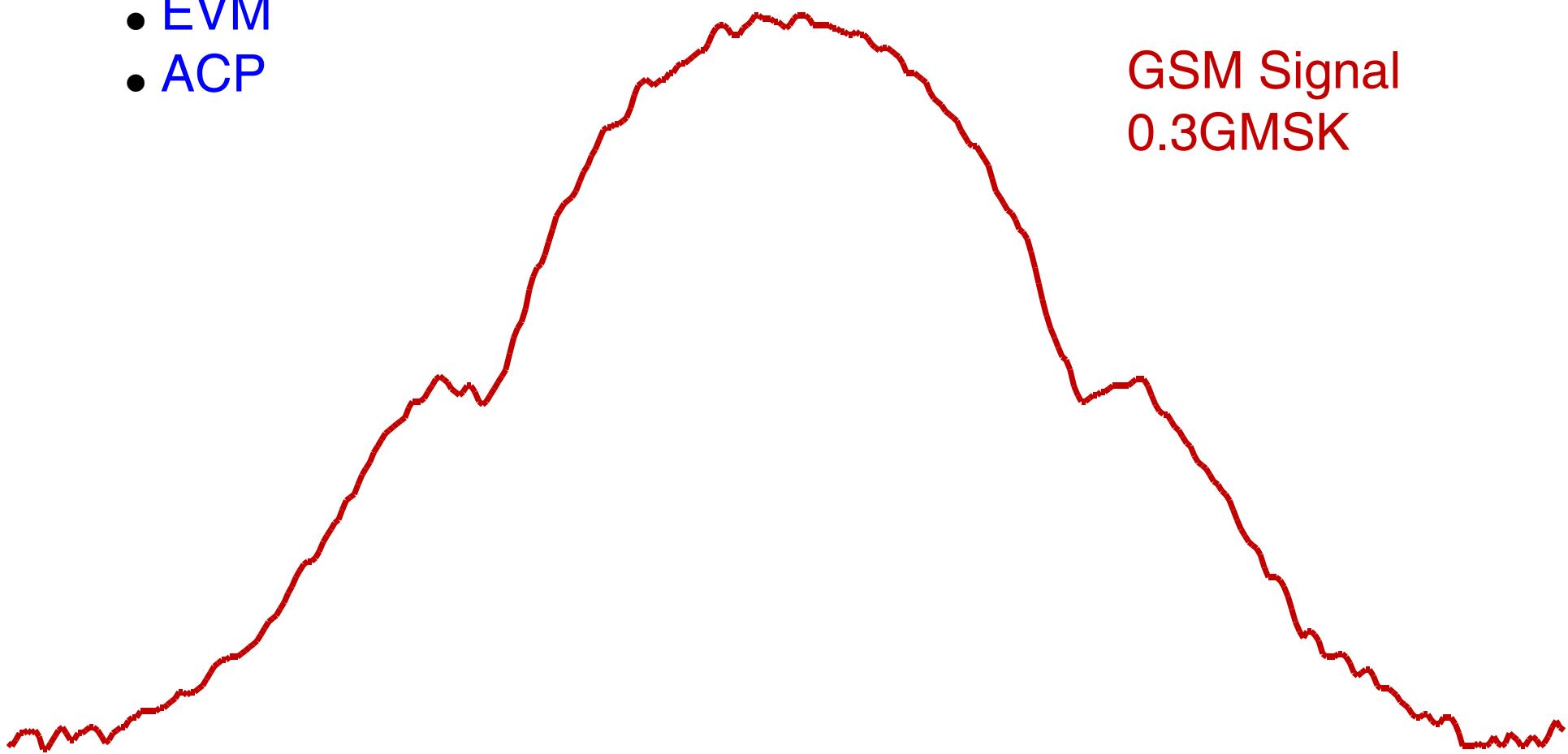
Signal generators: Apps & Critical Specs

Receiver Selectivity

Spectral Accuracy:
- EVM
- ACP

GSM Signal
0.3GMSK

Signal generators: Apps & Critical Specs

Spectral Regrowth

- ACP (Adjacent Channel Power) Performance

Output from amplifier

Input from signal generator