Fundamentals of Noise Figure Measurements

Vinod Malkani

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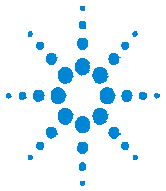
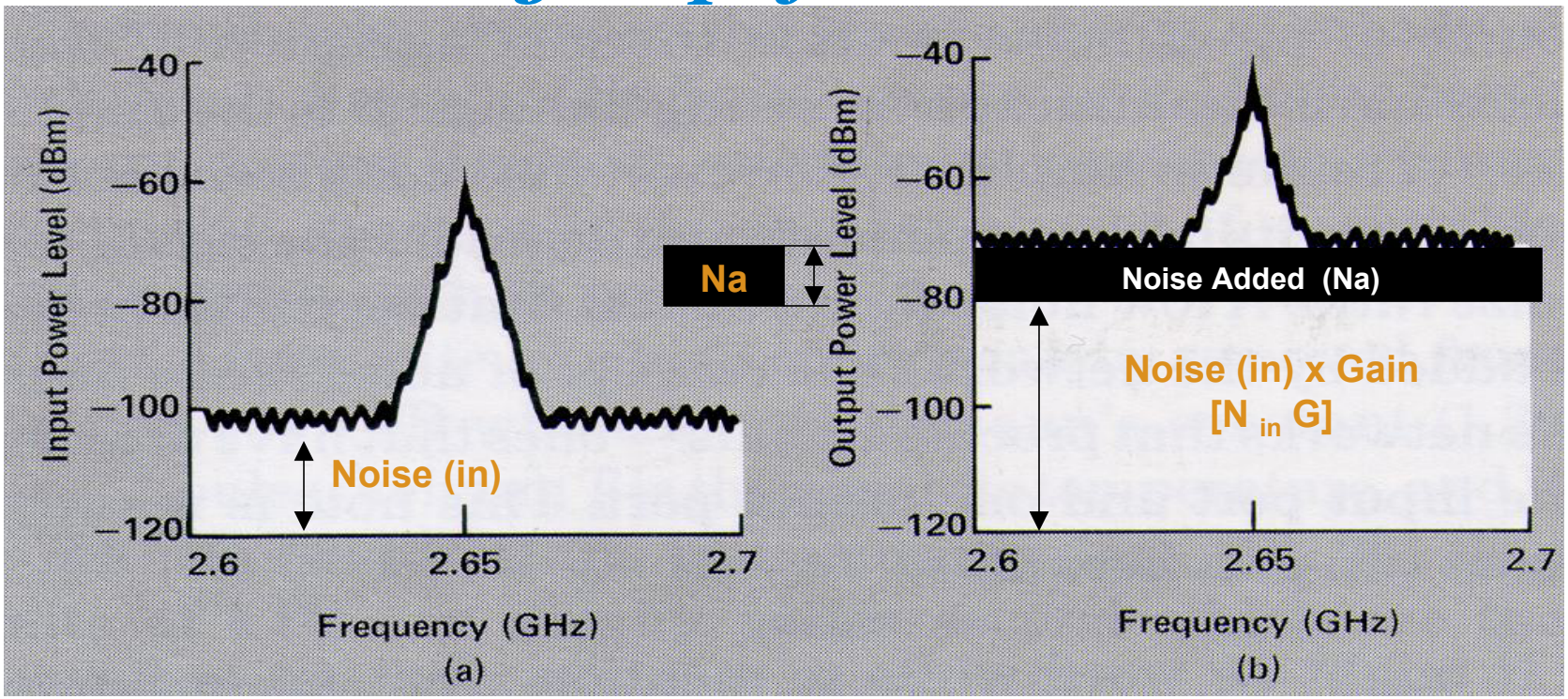
Key Topics and Objectives

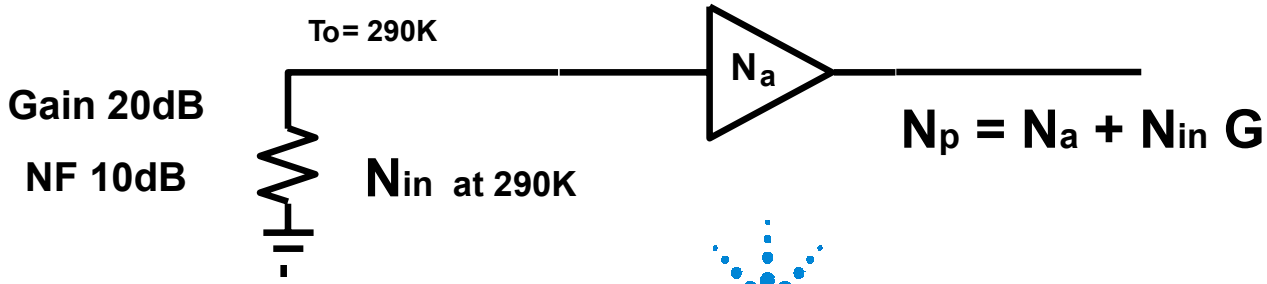
- What is noise figure?
- Why do we measure noise figure?
- How do we measure noise figure ?
- Why do we consider second stage contribution?
- What devices can be tested ?
- What factors affect accuracy?



What is noise figure?

Noise added by amplifier





Imperfect Amplifier Degrades Signal to Noise Ratio

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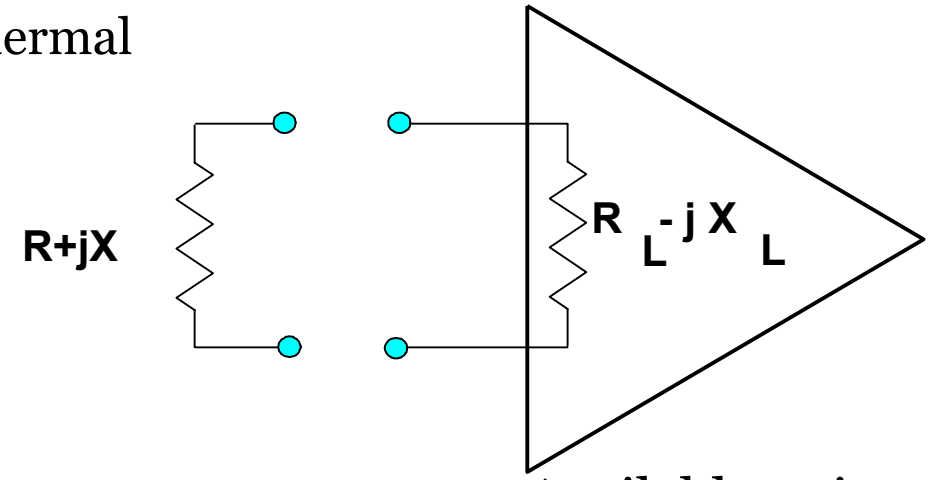
What is noise figure ? (cont)

Thermal



Available noise power

$$P_{av} = kTB$$

(Power delivered to a conjugate load),
(i.e. R = R, X = X)

k = 1.38 x 10 joule / k
T = Temperature (K)
B = Bandwidth (Hz)

Note: At Standard Temperature T (=290K) : kT = 4 x 10^{-21} W/Hz = -*174dBm / Hz*

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Why do we measure noise figure? Example...

C

Transmitter:

ERP	+ 55 dBm
Path Losses	-200 dB
Rcvr. Ant. Gain	60 dB
Power to Receiver	-85 dBm

D

Receiver:

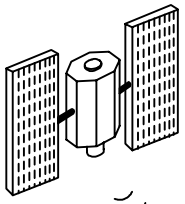
Noise Floor @ 290K	- 174 dBm/Hz
Noise in 100 MHz BW	+ 80 dB
Receiver N.F.	+5 dB
Receiver Sensitivity	-89 dBm

Link Margin: 4 dB

Power to Antenna: +40 dBm

Frequency: 12 GHz
Antenna Gain: +15 dB

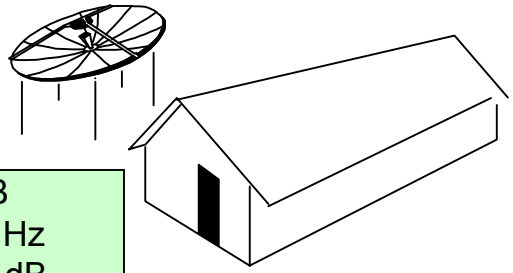
A



ERP = +55 dBm

Path Losses: -200 dB

B



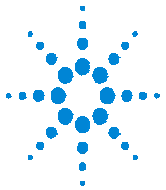
Receiver NF: 5 dB
Bandwidth: 100 MHz
Antenna Gain: 60 dB

Choices to Increase Margin

1. Increase transmitter power

2. increase gain of antennas

3. Lower the receiver N.F.



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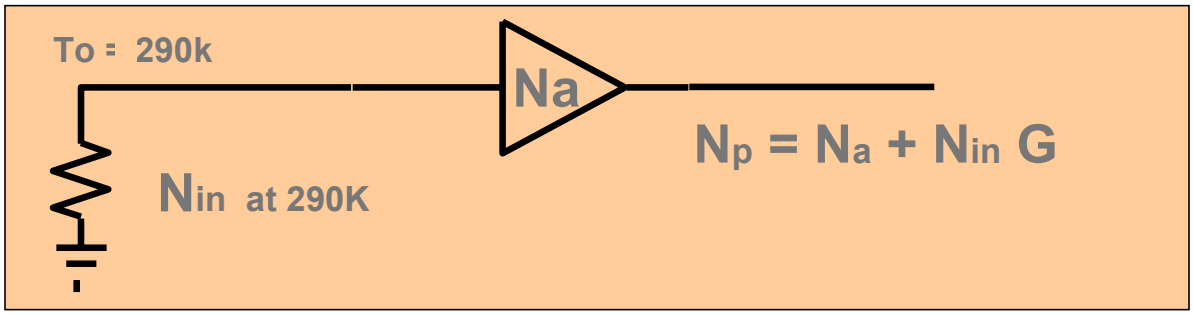
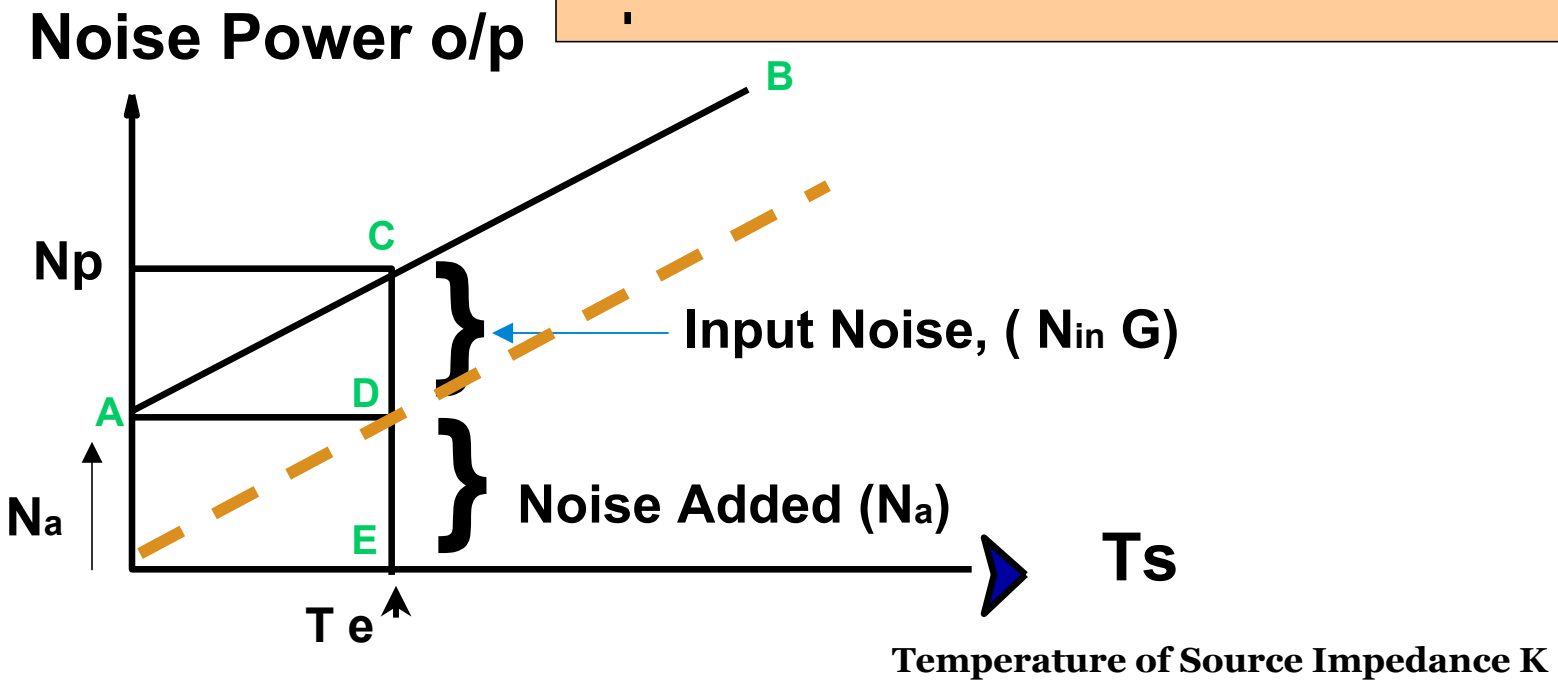
How do we measure noise figure ?





T e = Effective Noise Temperature

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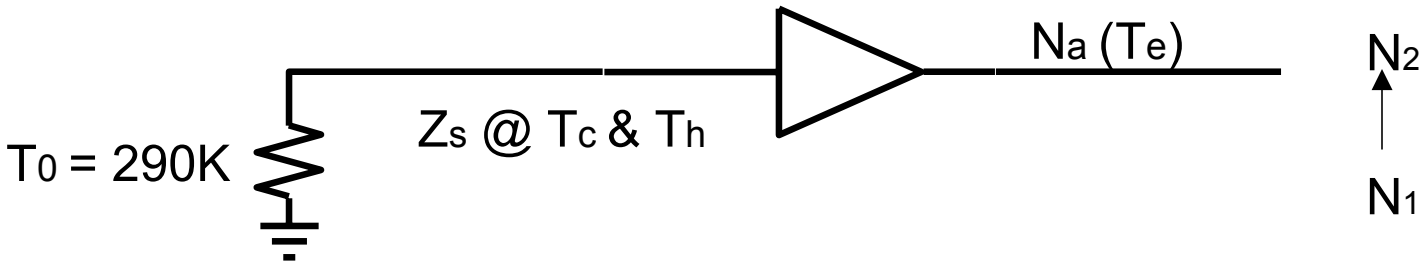
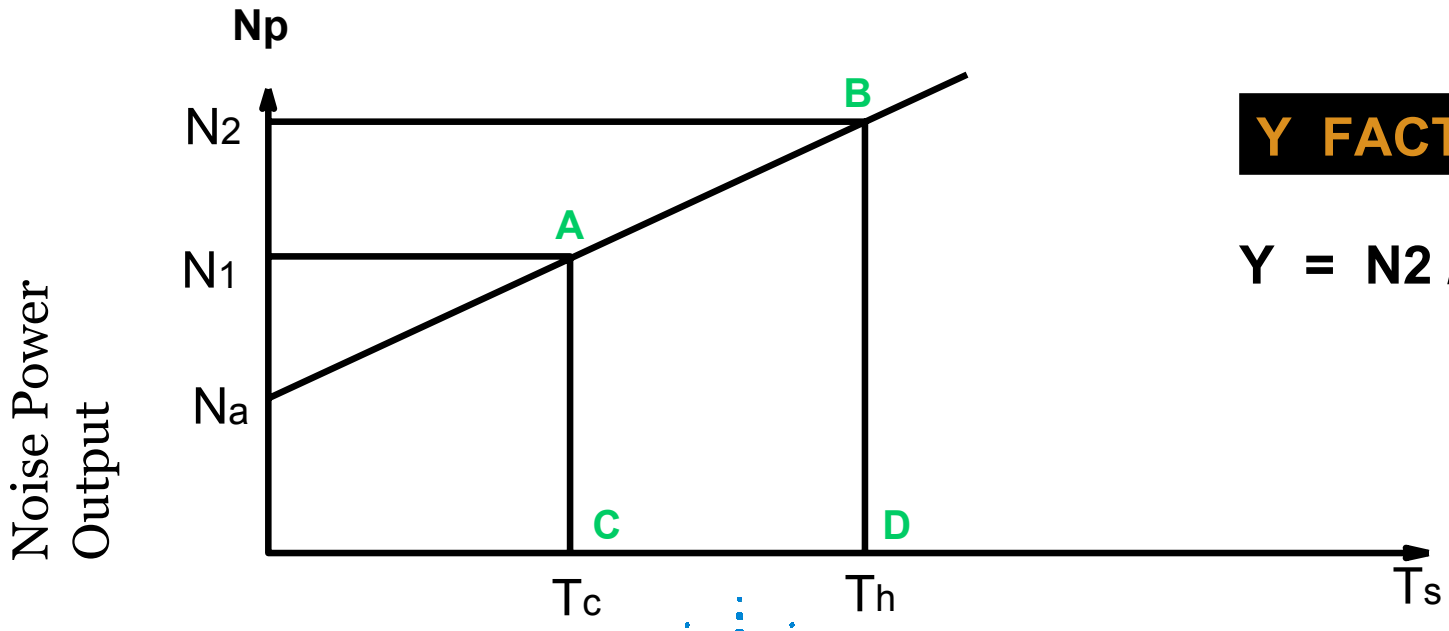
How do we measure noise figure ? (cont)



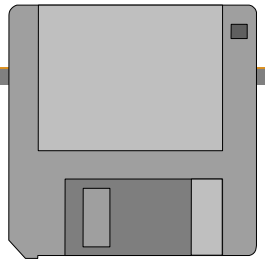


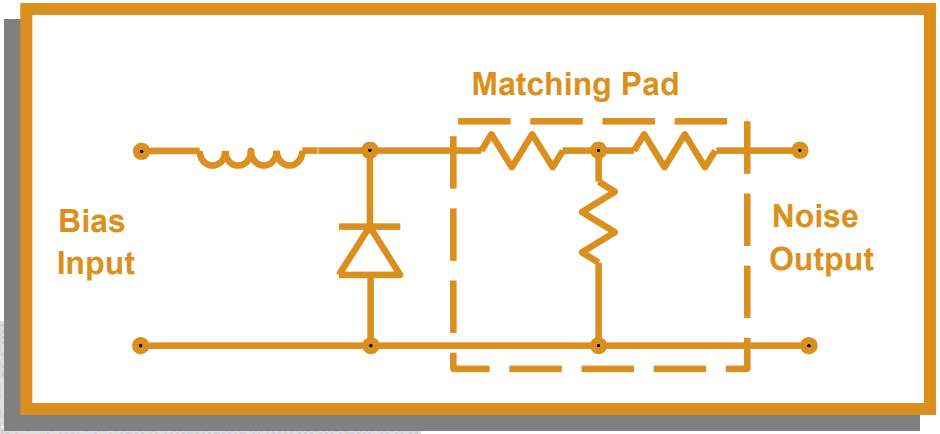
Y FACTOR

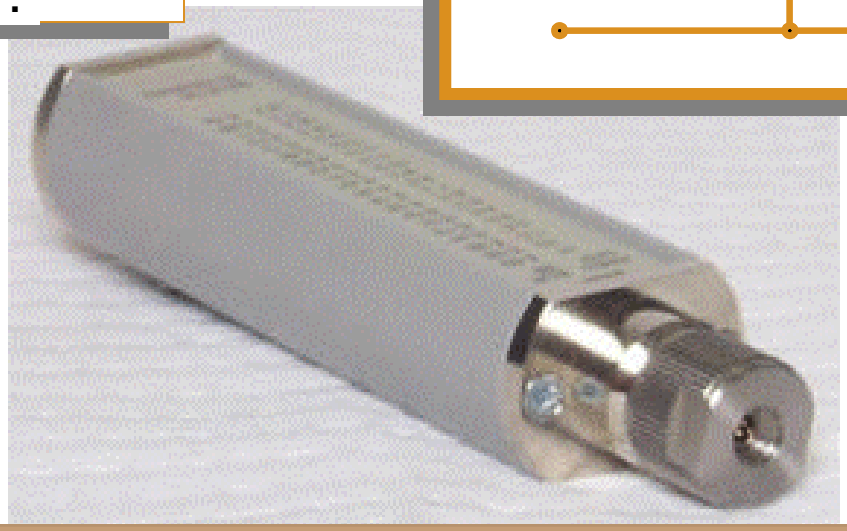
Y = N2 / N1

How do we measure noise figure ? (cont)
Noise Source Avalanche Diode

Frequency	ENR dB
XXX	AAA
YYY	BBB
ZZZ	CCC
⋮	⋮







$$\text{Excess Noise Ratio, ENR (dB)} = 10 \log_{10} \frac{(T_h - 290)}{290}$$

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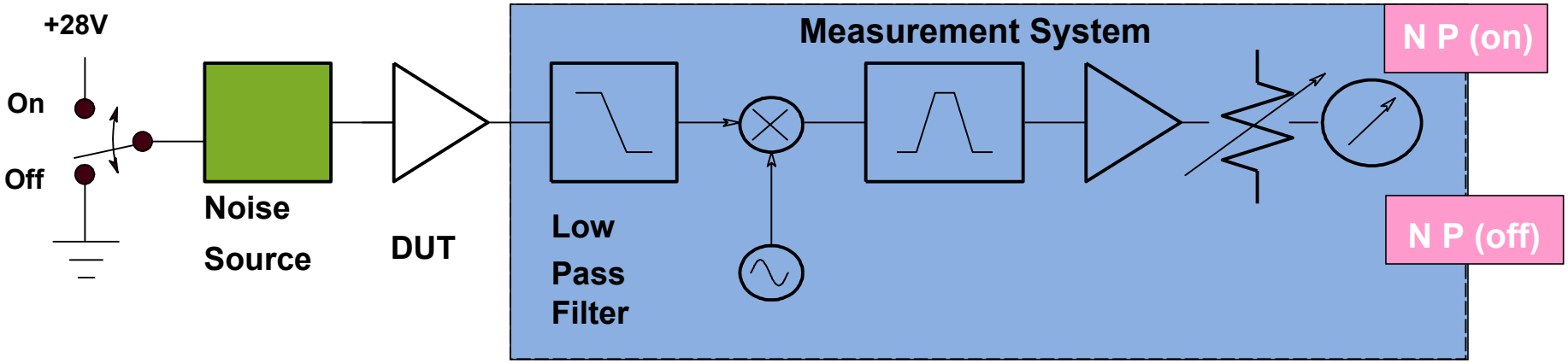
How do we measure noise figure ? (cont)



$$NF = ENR - 10 \log (Y-1)$$

Y = Np (on) / Np (off) = change in detected power level as source switches from Tc to Th

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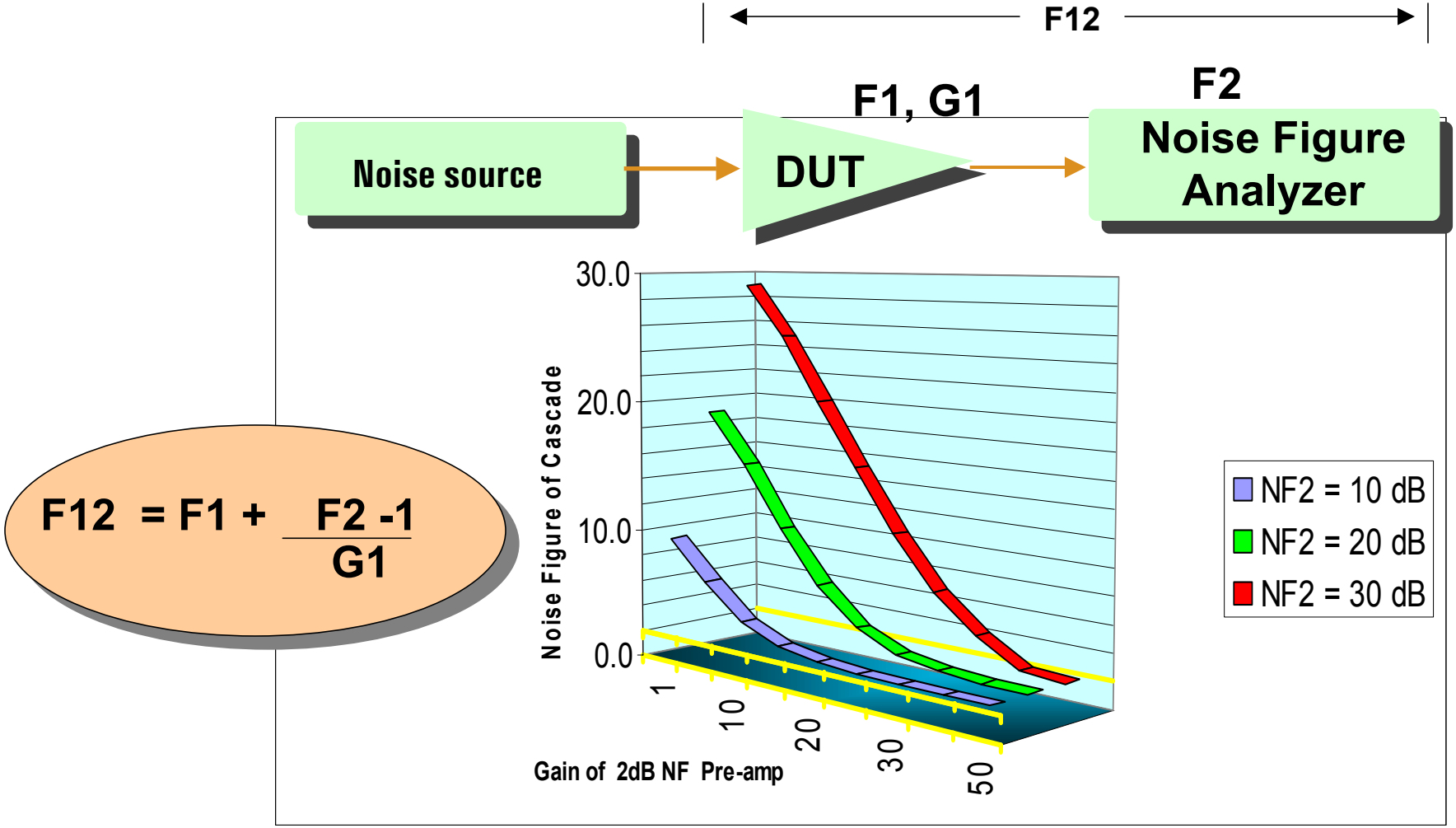
Why do we consider 2nd stage contributions?
Effect of DUT gain on total noise figure



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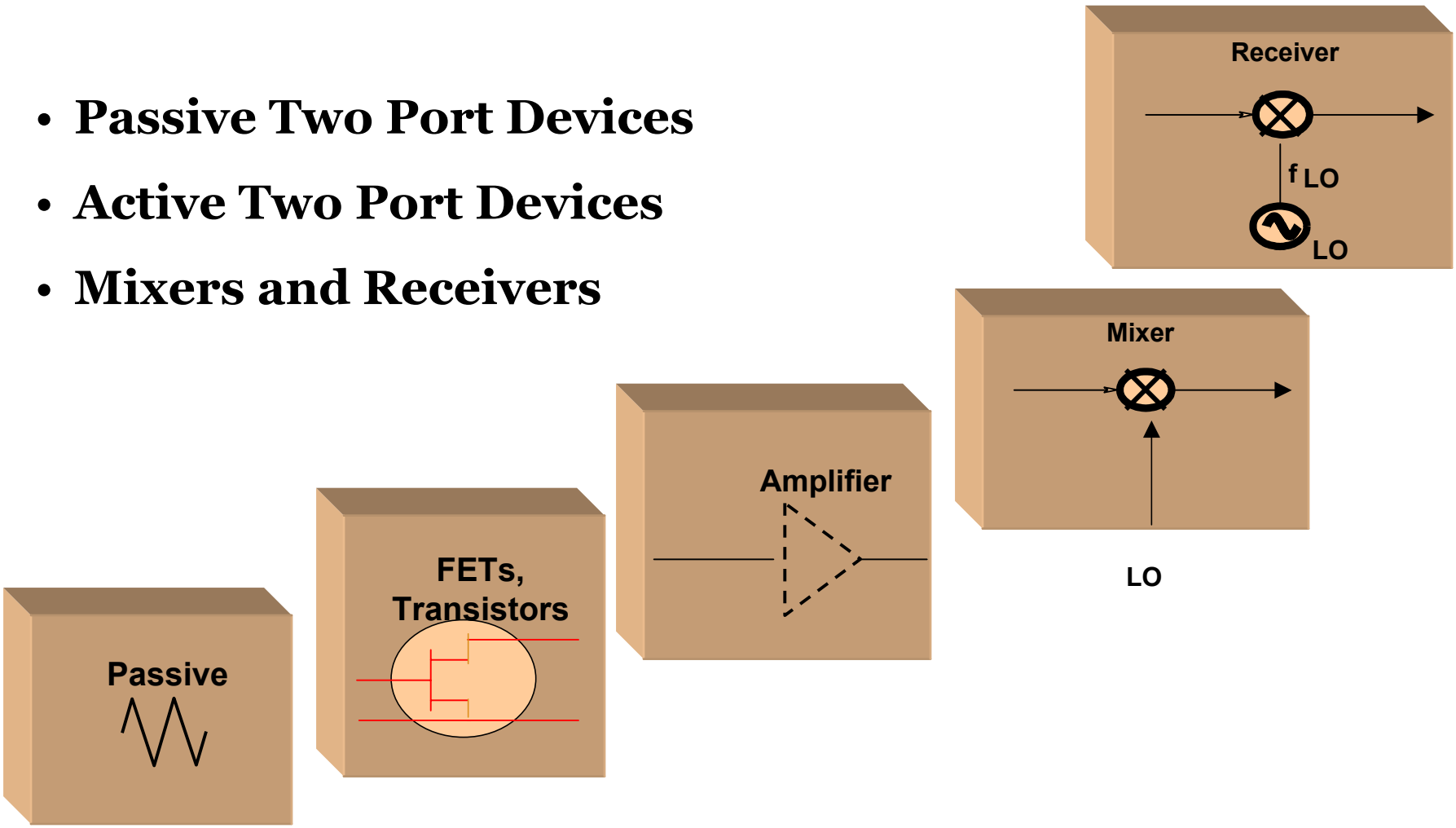
What devices can be tested?

- Passive Two Port Devices
- Active Two Port Devices
- Mixers and Receivers



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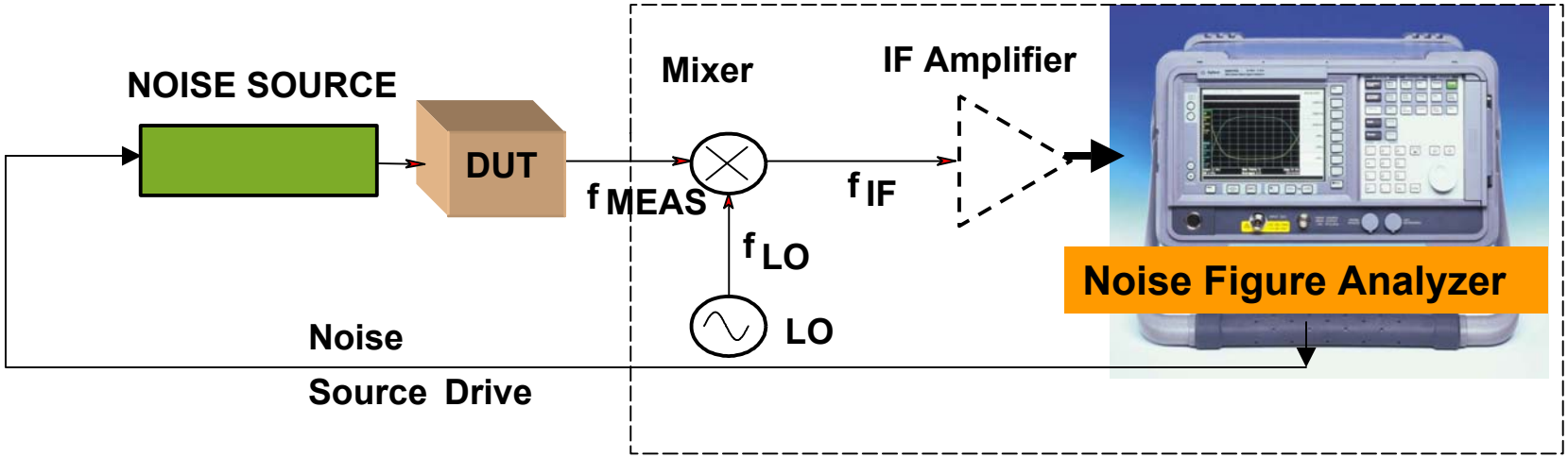
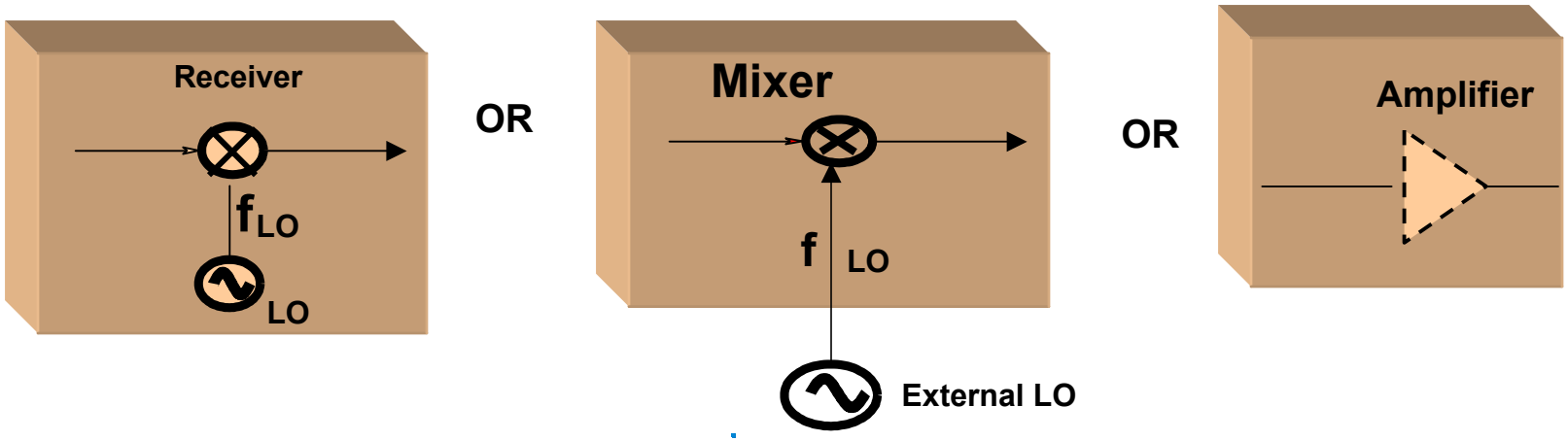
What devices can be tested? (cont)



Example :DUT =



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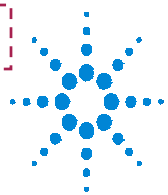
Factors affecting measurement accuracy:

- Extraneous signals
- Non-linearity of the DUT
- Instrumentation uncertainty
- ENR uncertainty
- Uncertainty due to mismatch
- Unwanted in-band power
- System response characteristics (DSB, SSB, Harmonics)
- Gain and noise figure of device
- System noise figure (2nd stage contribution)
- Poor connectors
- Source impedance
- Display jitter
- Ambient temperature
- Loss compensation uncertainties



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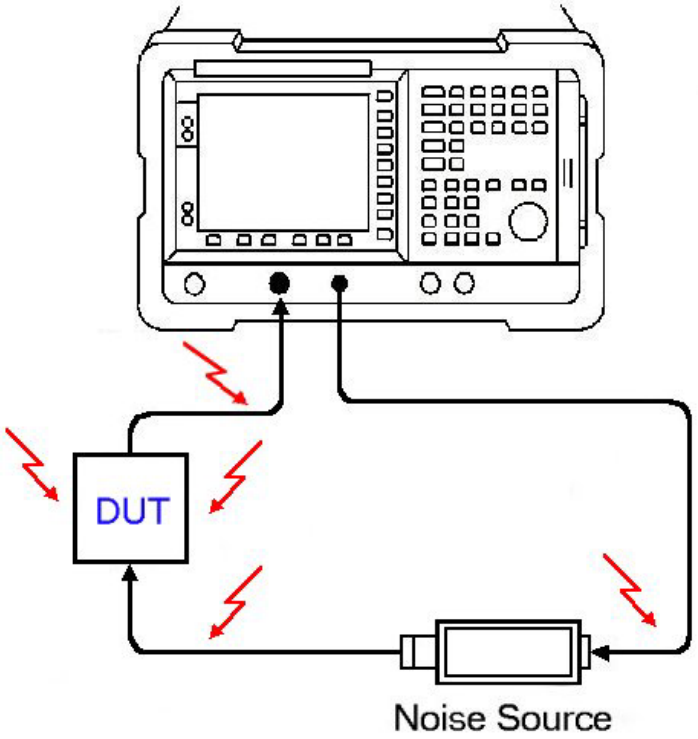
Extraneous signals

- Pocket Pagers
- Security communication systems
- Mobile/Cordless phones
- WLAN
- Choice of measuring instrument
- DUT's are often connected directly to the instrument
- Good instruments have very low emissions in the near field



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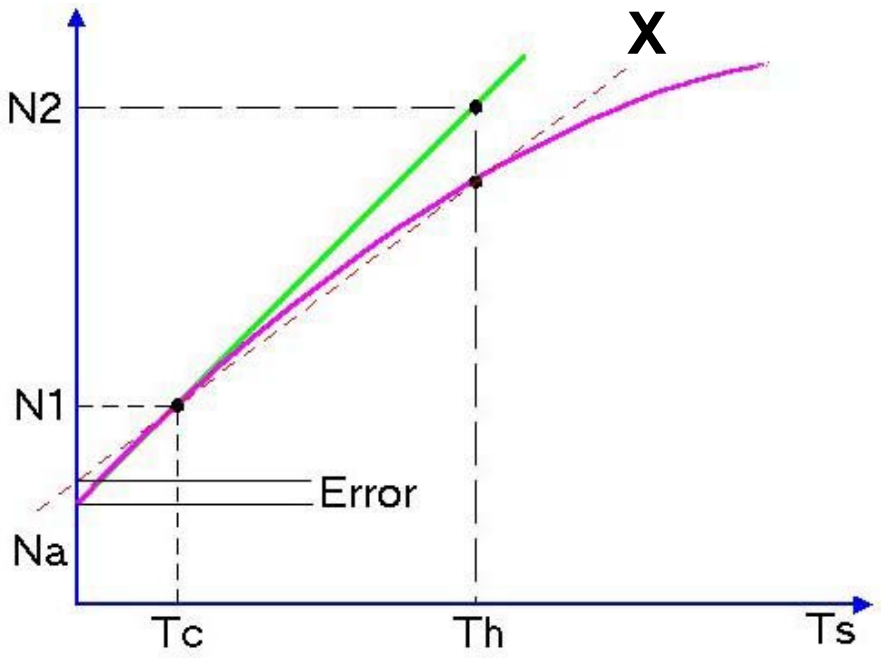
Non-linearities

- Non-linearities distort the Y-Factor
- This translates through to the noise figure
- No saturation in amplifiers or mixers
- No AGC or Limiters
- No squelch
- Measure sub-circuitry before loops, AGC etc are added



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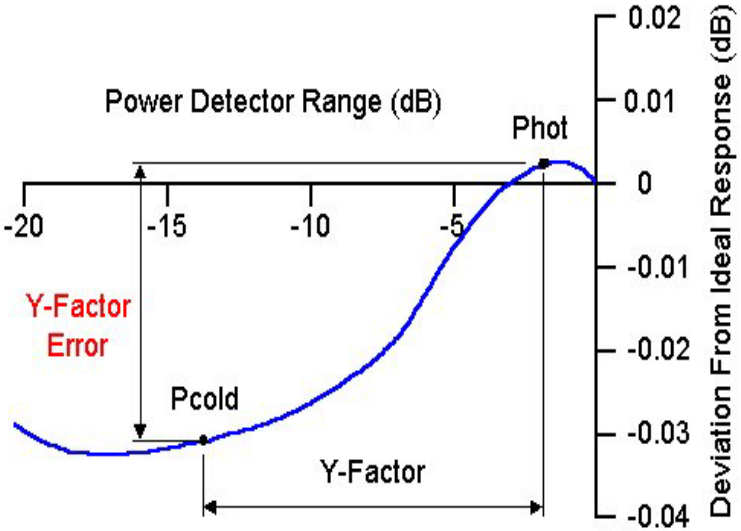
Instrumentation uncertainty

- Detector linearity is a prime contributor to the overall uncertainty
- Effect, not reduced by DUT gain
- Differences of as little as 50mdB between different instruments have a significant effect
- Principal Spec when choosing an instrument
- Y factor error adds uncertainty to the calculation [NF = ENR - 10log (Y-1)]



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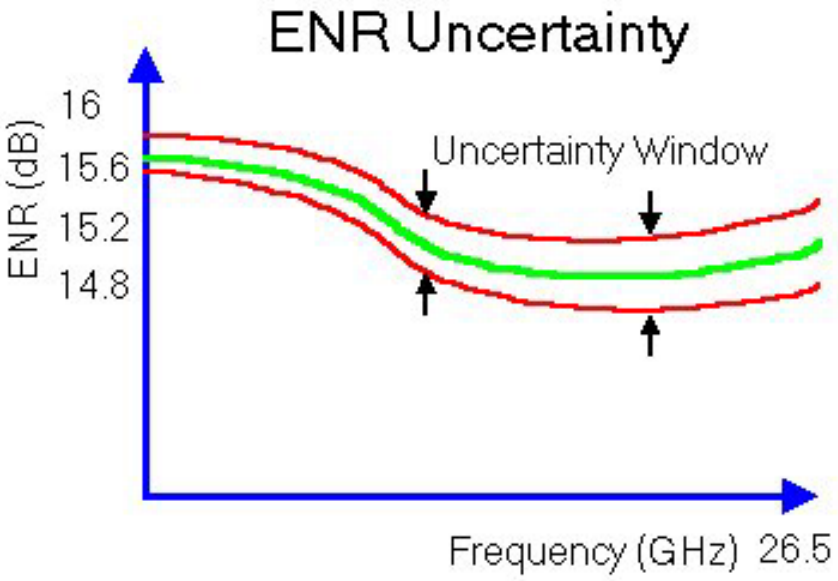
Excess Noise Ratio (ENR) uncertainty

- Uncertainty in the noise power from the noise source is a very big player
- Referenced to National Institute of Standards and Technology (NIST)
- Ensure the ENR table in the instrument is for the source in use
- Ensure there are no errors in the table entries
- NFA series allows the table to be loaded from disk or GPIB



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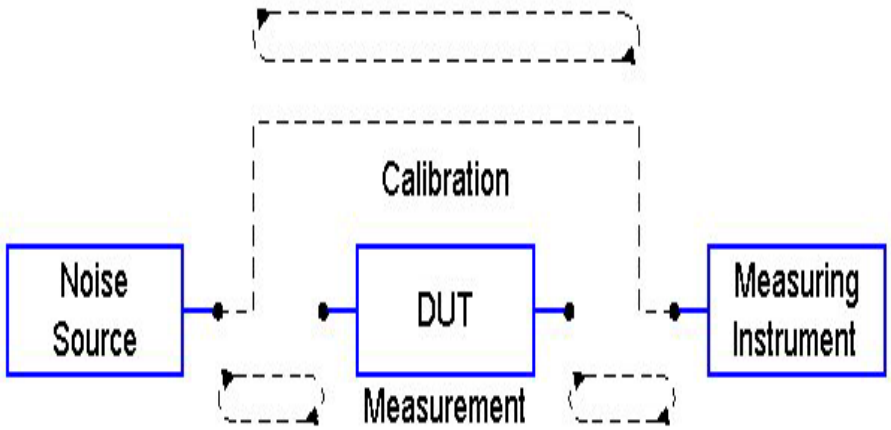
Mismatch uncertainty

- Complicated subject in the context of noise figure
- Noise source VSWR is a big player
- Effects of other players reduce with increased DUT gain
- Isolators between the noise source and DUT can help but bring other uncertainties
- Using S-Parameters will cause further errors unless accompanied by noise parameters



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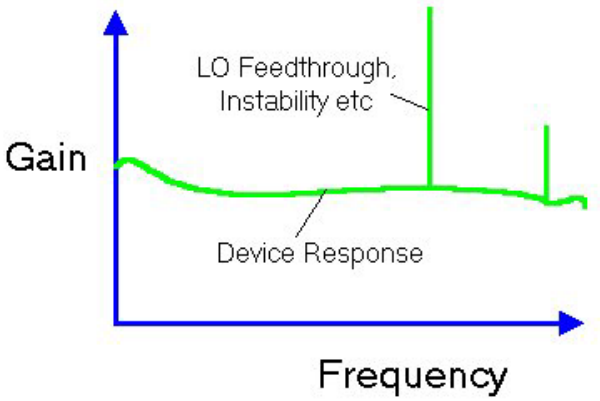
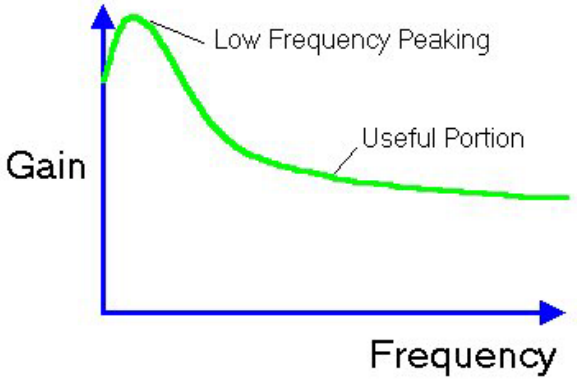
Unwanted in-band power

- High levels of unwanted in-band power will cause the analyzer to select a poor range for the measurement
- High instrument noise figure
- Keep LO's well out of the band of the instrument
- Ensure devices are stable and free from oscillations
- Filter unwanted amplifier responses



GaAs Amplifier Response



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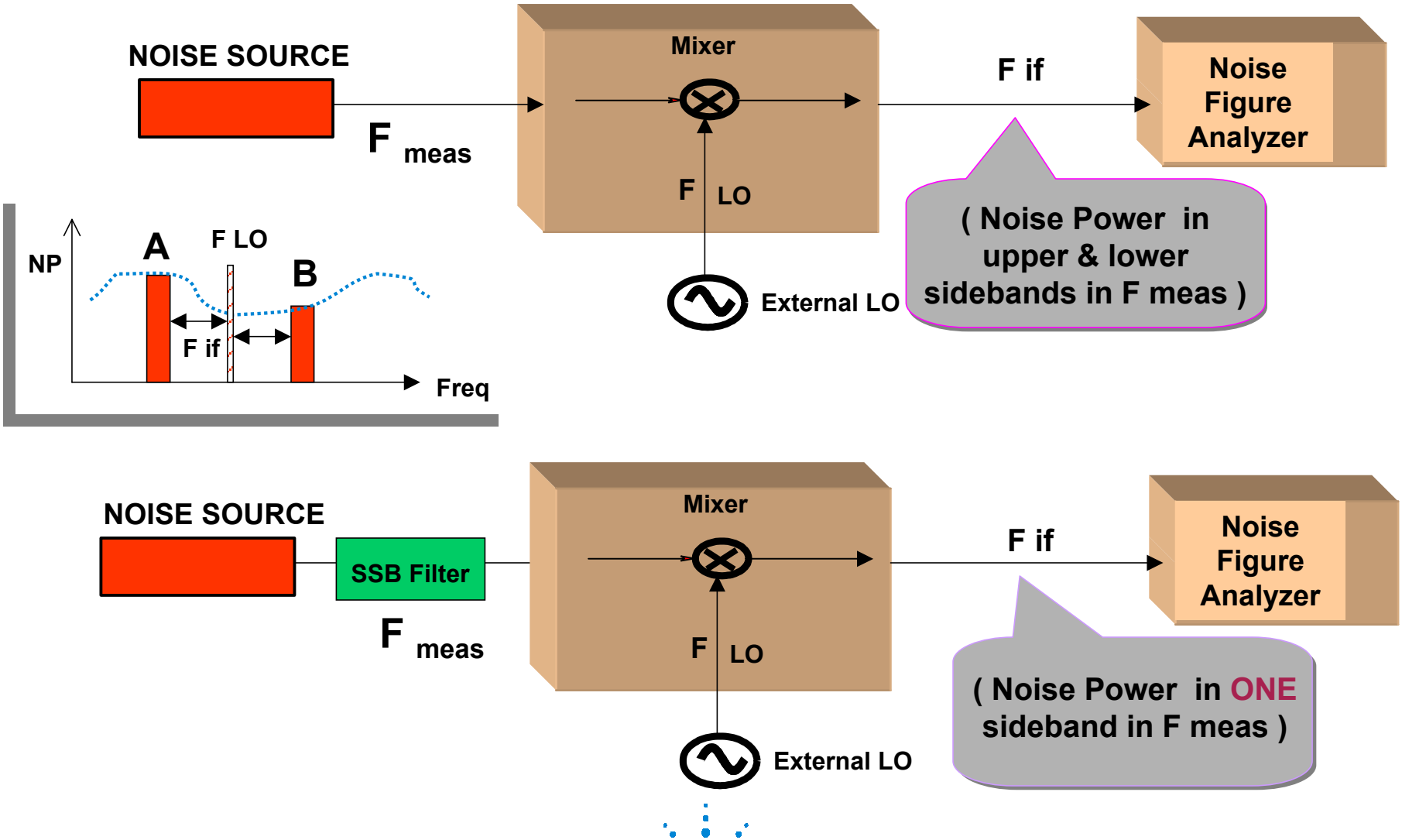
Mixer measurements (SSB v DSB)



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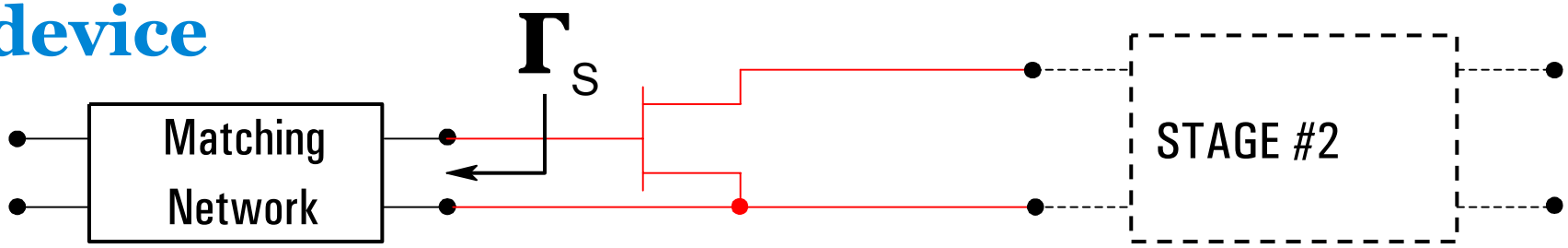
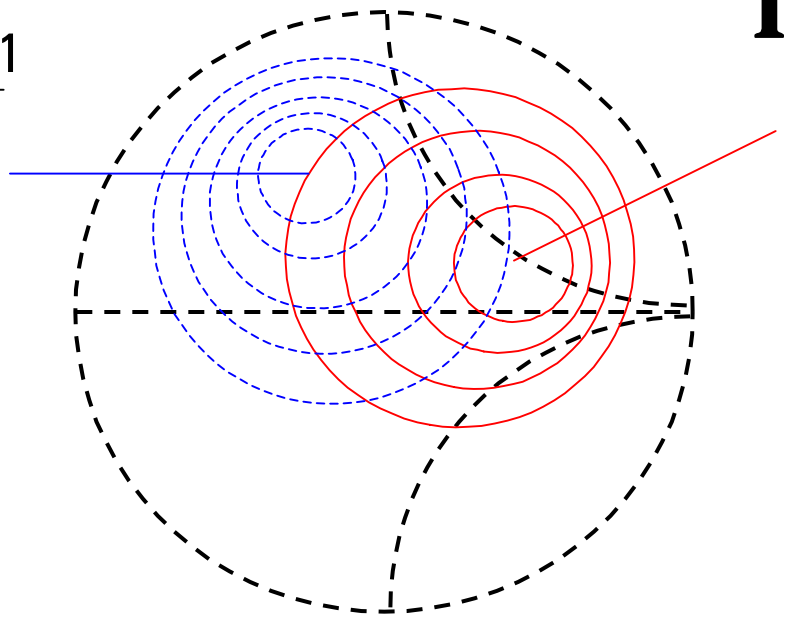
Gain and noise figure of the device



Γ_{MAX} = 0.64 ∠101

F = 3.37 dB

G_a = 0.53 dB



Γ_{OPT} = 0.43 ∠23

F = 1.45 dB

G_a = -2.77 dB

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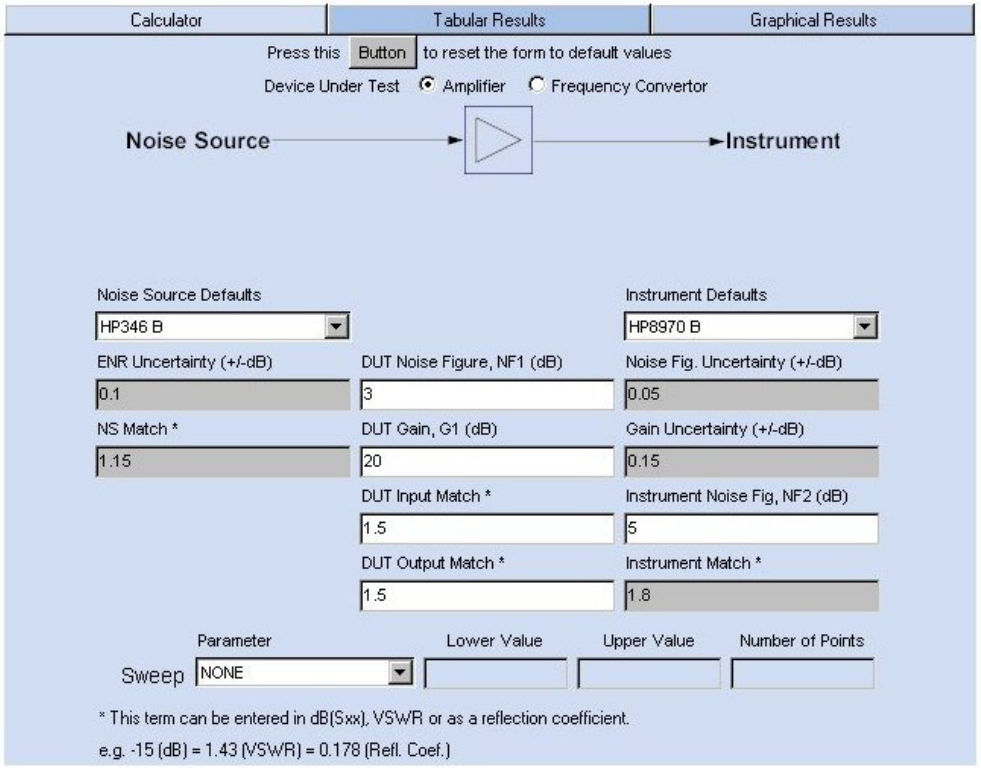
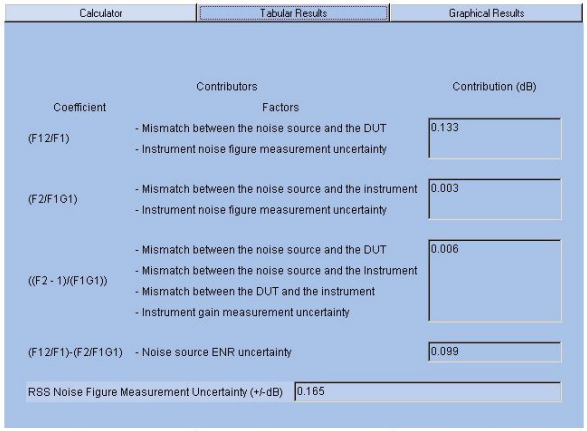
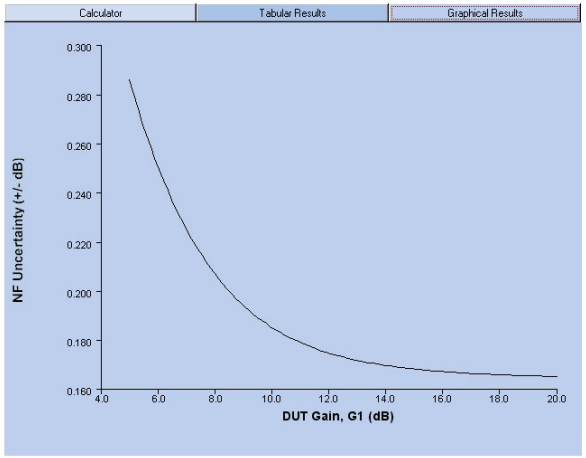
Web based measurement uncertainty calculator

Data Entry



Results





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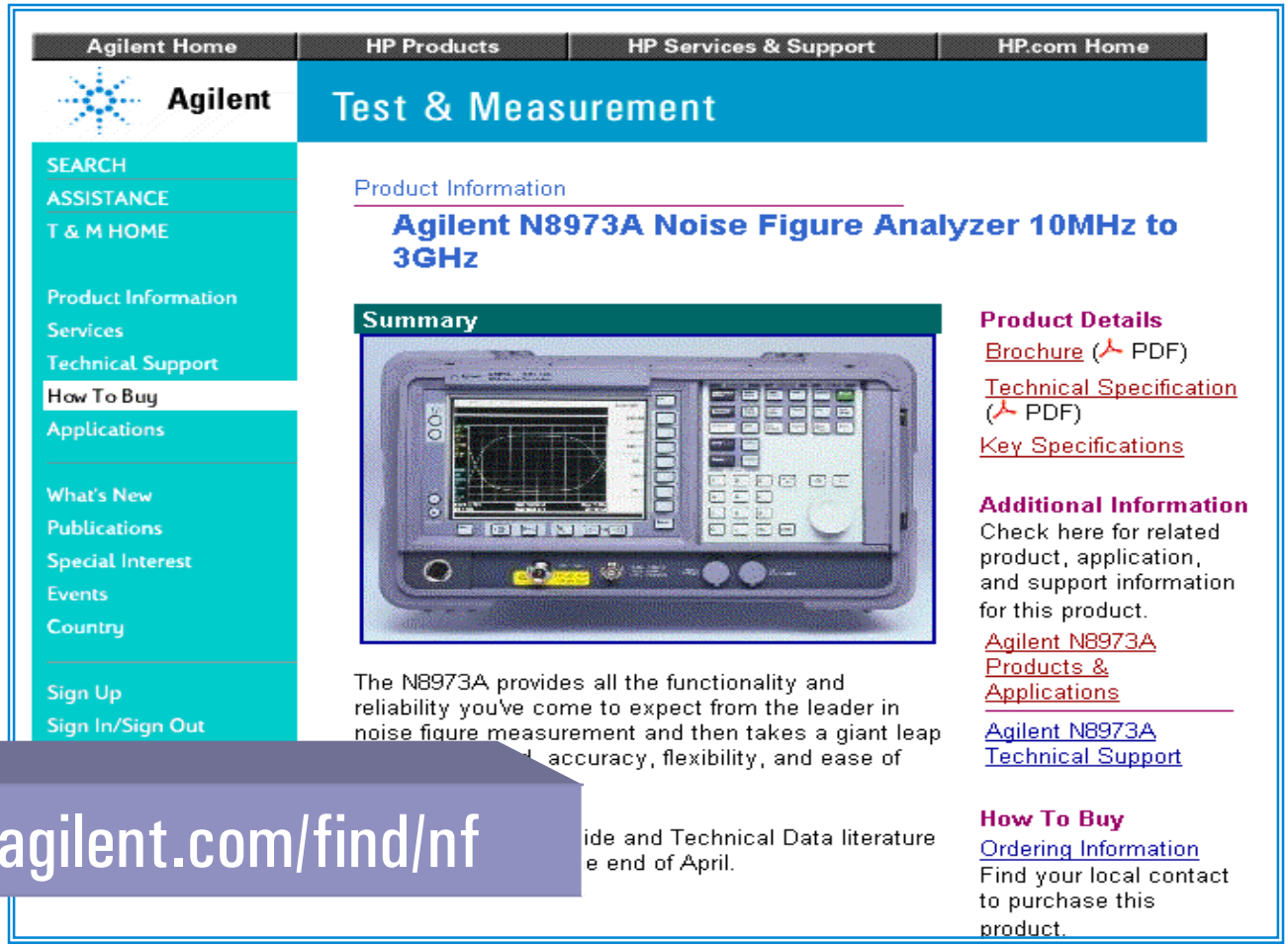
To find out more on noise figure solutions:



http://www.agilent.com/find/nf

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