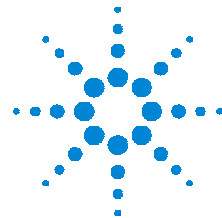


Fundamentals of Noise Figure Measurements

Vinod Malkani

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Innovating the HP Way

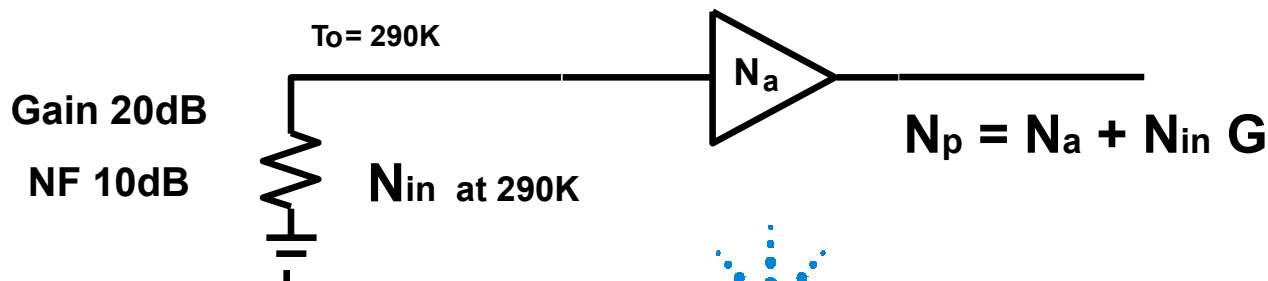
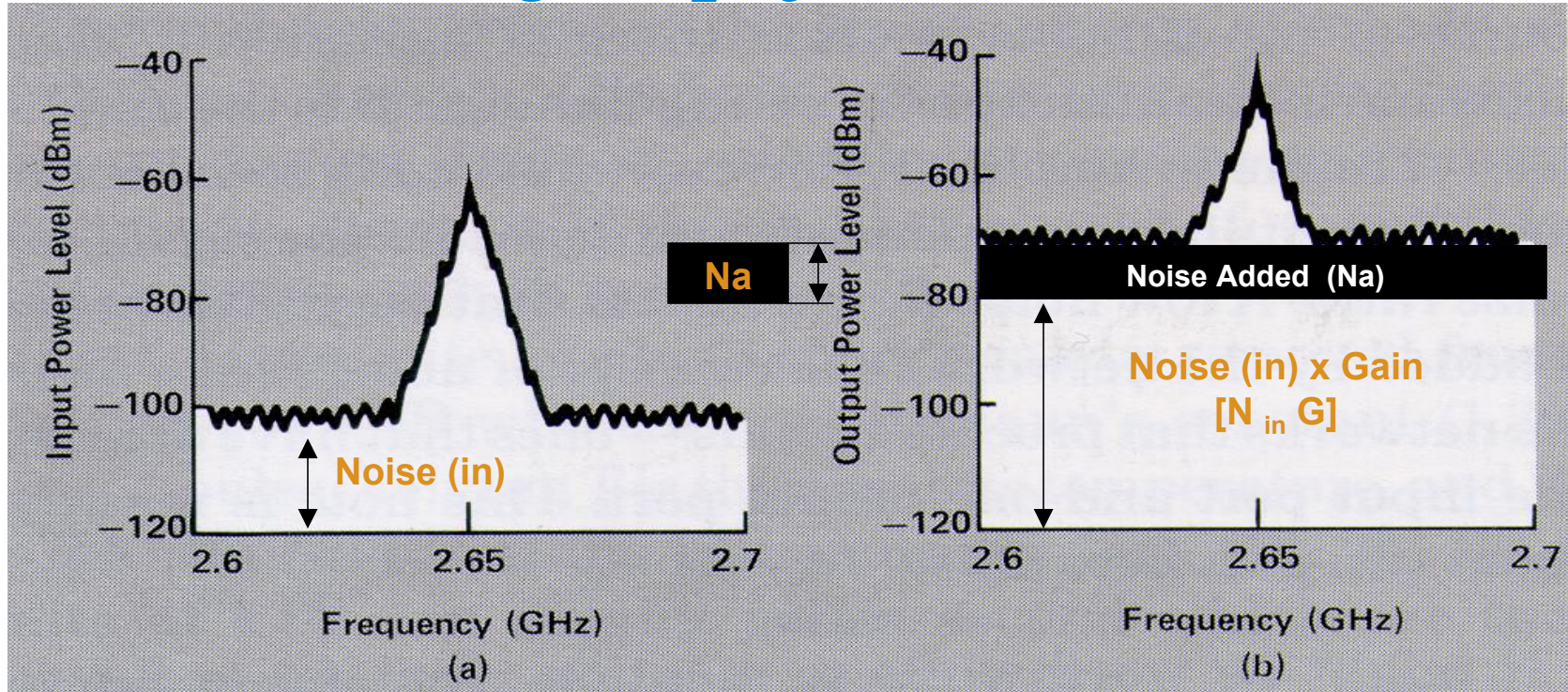
Key Topics and Objectives

- **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?**

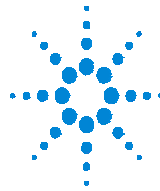


What is noise figure?

Noise added by amplifier



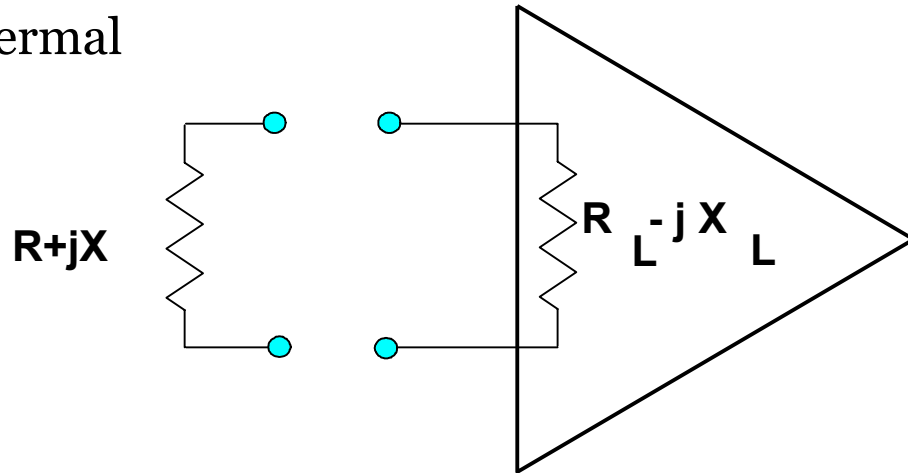
Imperfect Amplifier Degrades Signal to Noise Ratio



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What is noise figure ? (cont)

Thermal



$$k = 1.38 \times 10^{-23} \text{ joule / K}$$

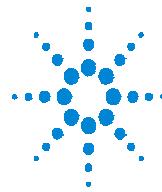
$T = \text{Temperature (K)}$
 $B = \text{Bandwidth (Hz)}$

Available noise power

$$P_{av} = kTB$$

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

Note: At Standard Temperature $T (=290K)$: $kT = 4 \times 10^{-21} \text{ W/Hz} = \underline{\underline{-174dBm / Hz}}$



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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
<hr/>	
Power to Receiver	-85 dBm

D

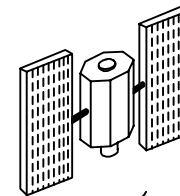
Receiver:

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

Link Margin: 4 dB

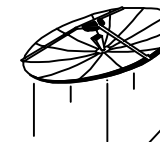
Power to Antenna: +40 dBm
Frequency: 12 GHz
Antenna Gain: +15 dB

A



ERP = +55 dBm

B

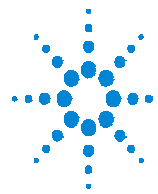


Path Losses: -200 dB

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

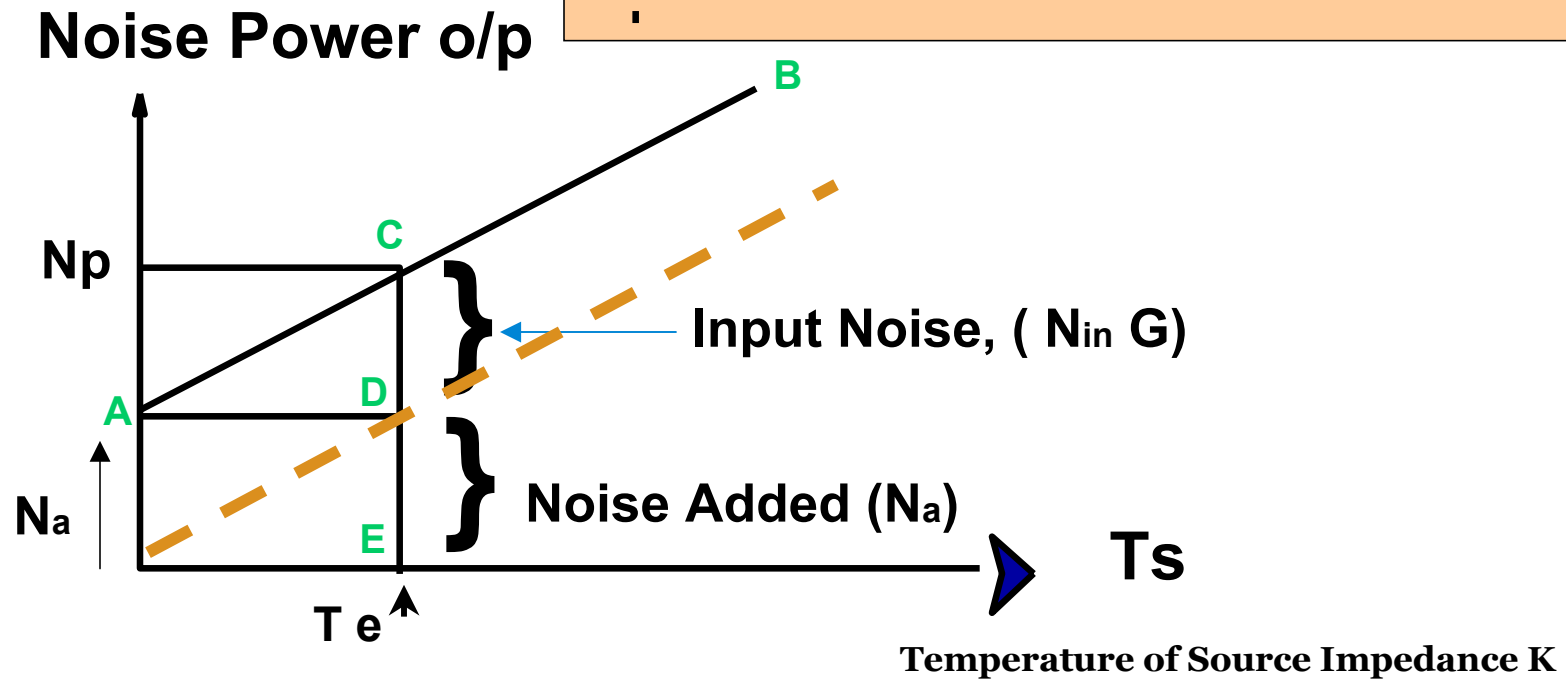
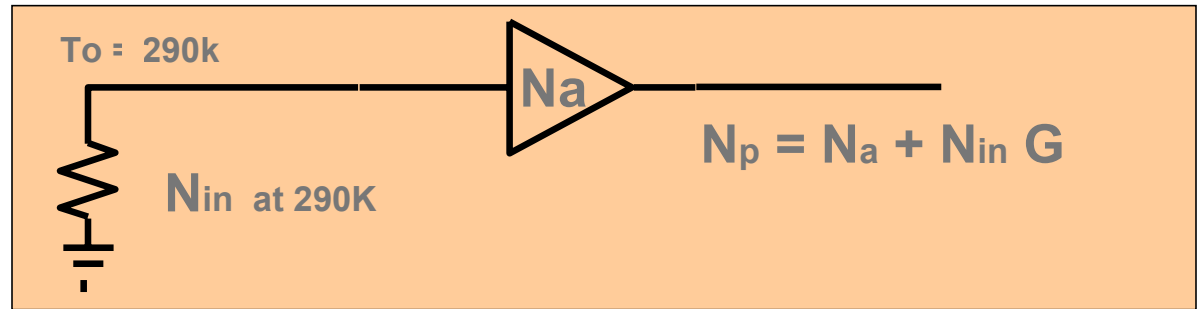
Choices to Increase Margin

1. Increase transmitter power
2. increase gain of antennas
3. Lower the receiver N.F.

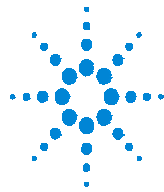


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How do we measure noise figure ?

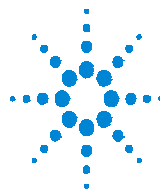
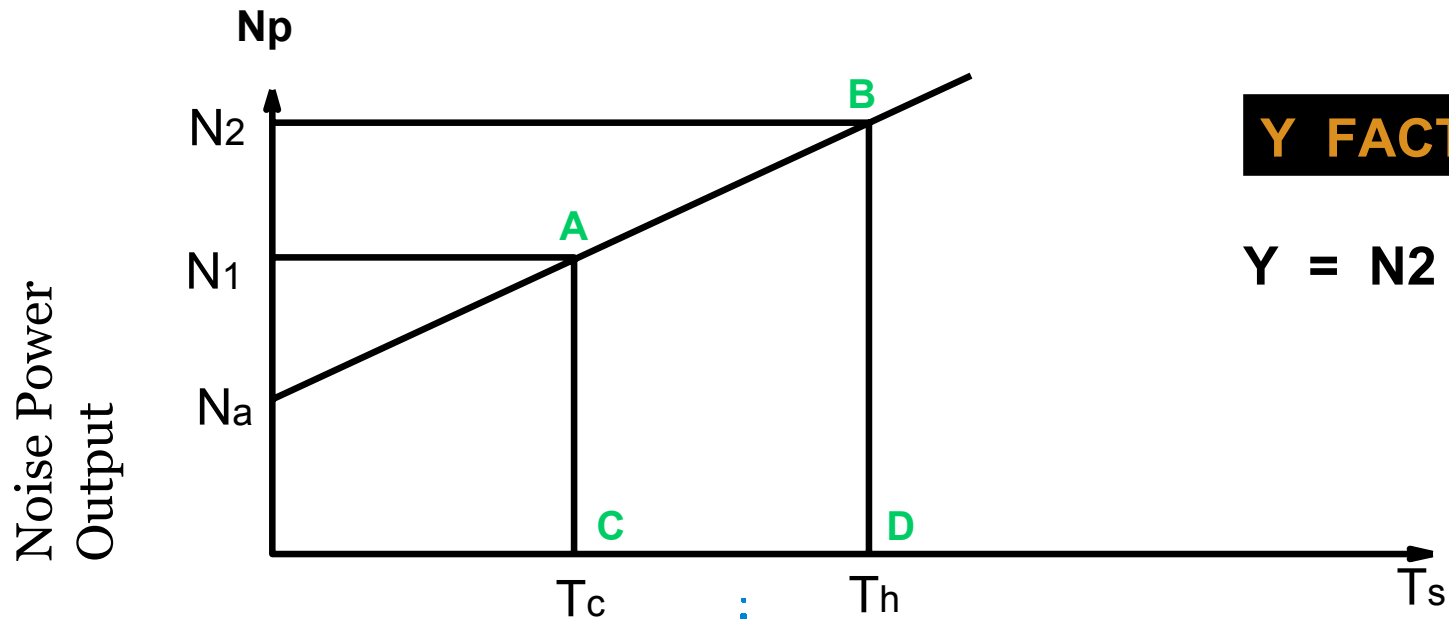
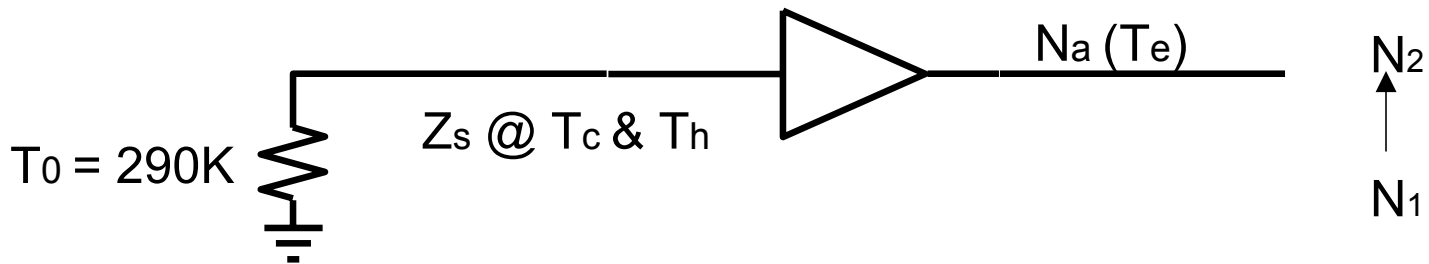


T_e = Effective Noise
 Temperature



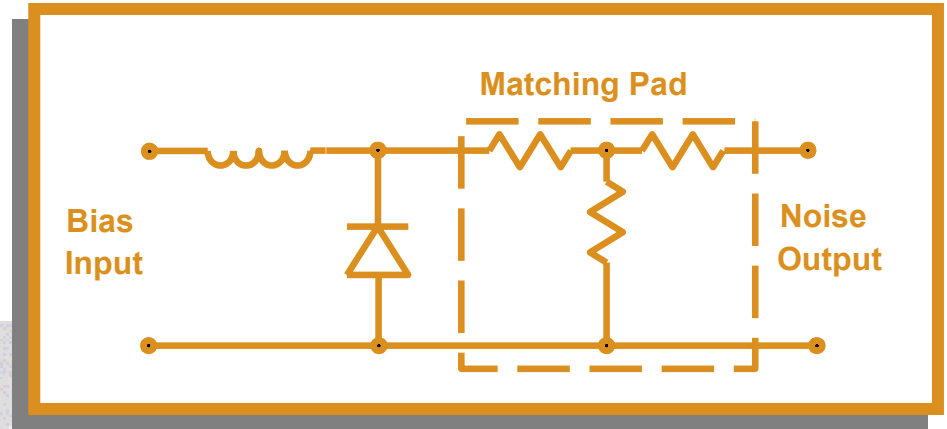
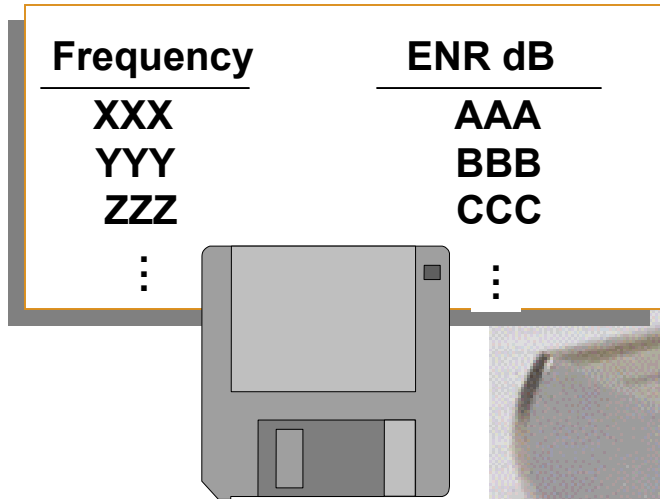
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How do we measure noise figure ? (cont)



How do we measure noise figure ? (cont)

Noise Source Avalanche Diode

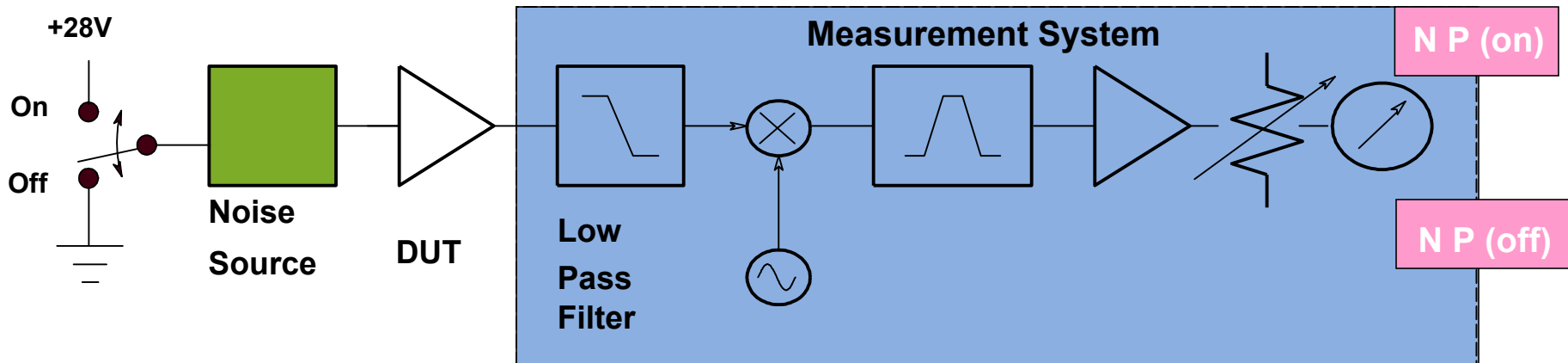


$$\text{Excess Noise Ratio, ENR (dB)} = 10 \text{ Log}_{10} \left(\frac{T_h - 290}{290} \right)$$



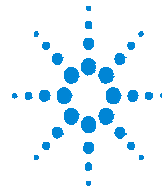
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How do we measure noise figure ? (cont)



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

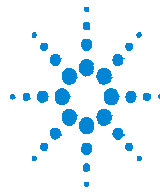
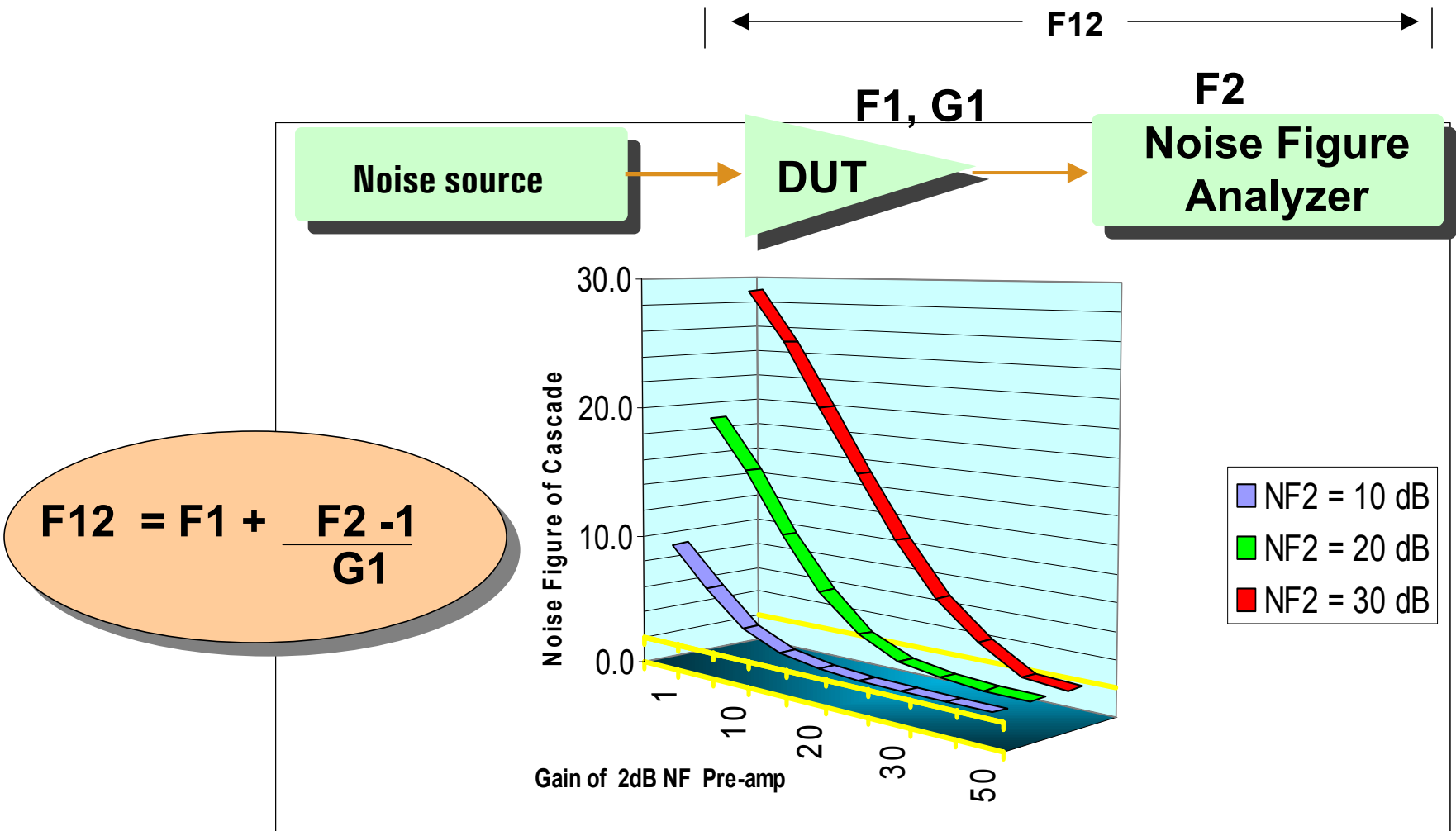
$Y = N_p(\text{on}) / N_p(\text{off}) =$
change in detected power
level as source switches
from T_c to T_h



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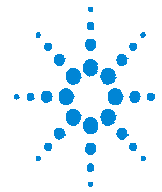
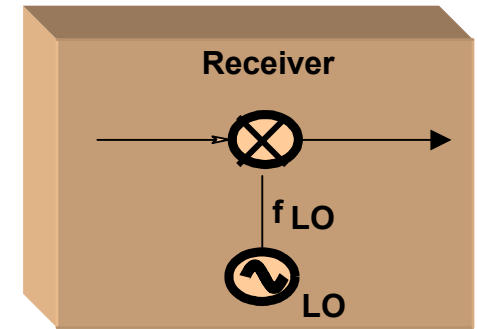
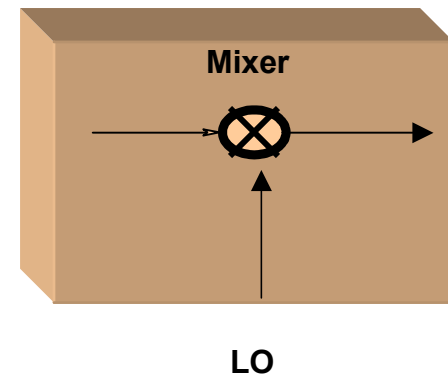
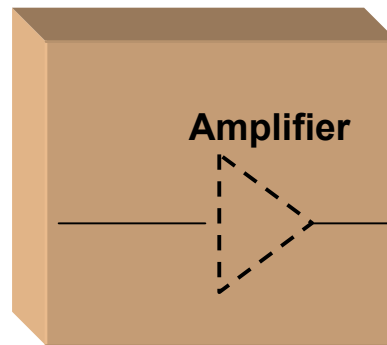
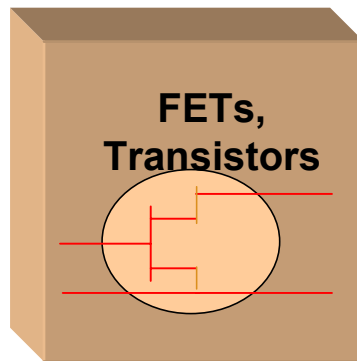
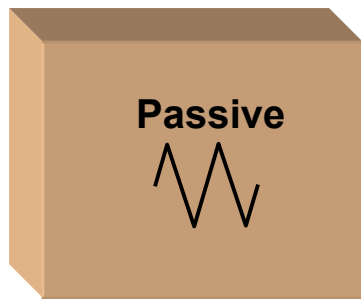
Why do we consider 2nd stage contributions?

Effect of DUT gain on total noise figure

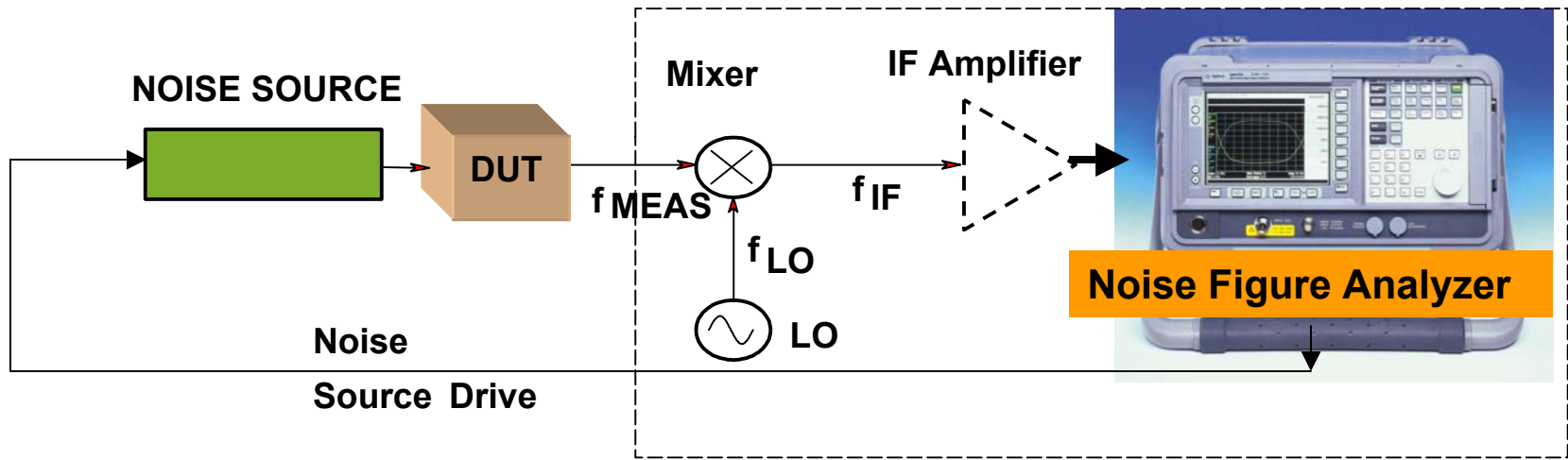


What devices can be tested?

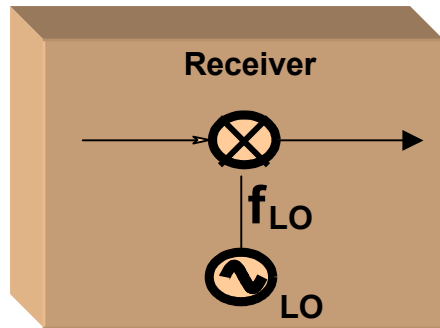
- **Passive Two Port Devices**
- **Active Two Port Devices**
- **Mixers and Receivers**



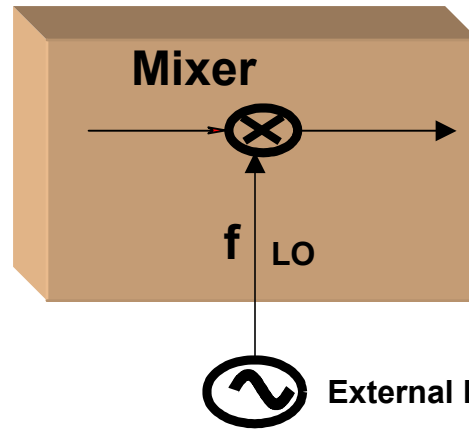
What devices can be tested? (cont)



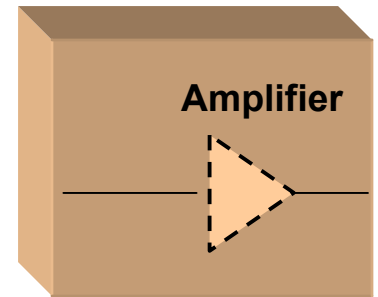
Example :DUT =



OR



OR



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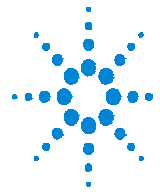
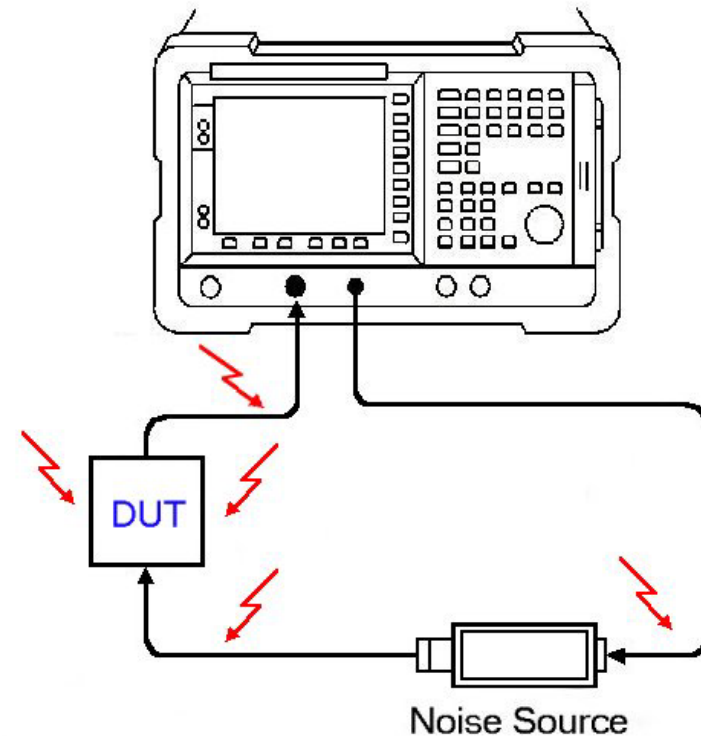
Factors affecting measurement accuracy:

- 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



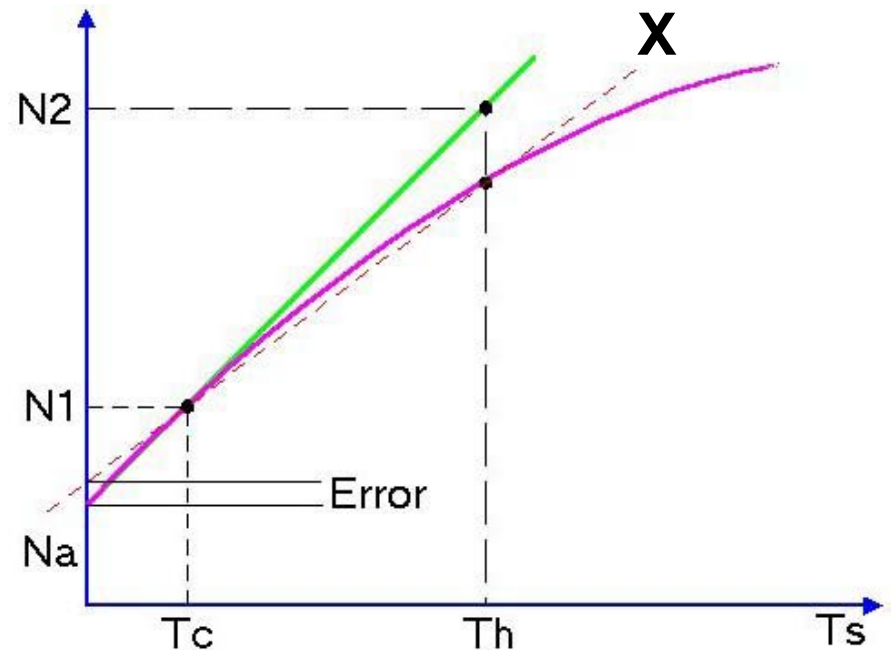
Extraneous signals

- 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



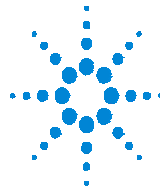
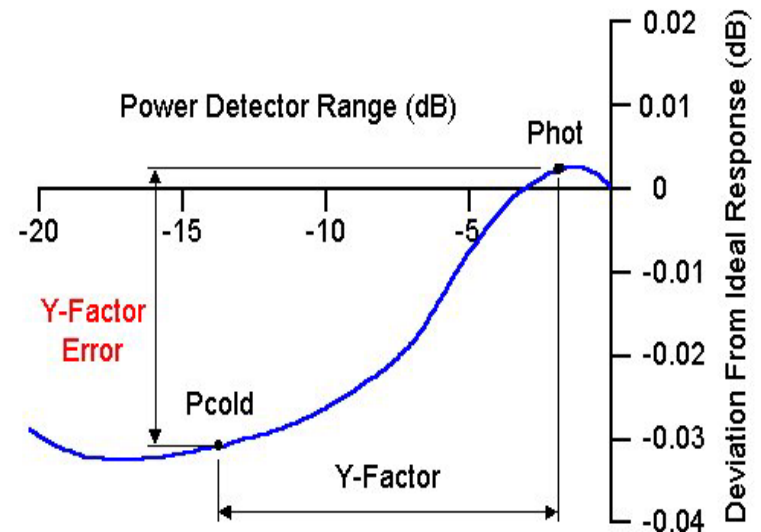
Non-linearities

- 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



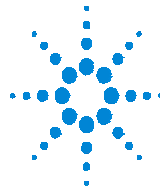
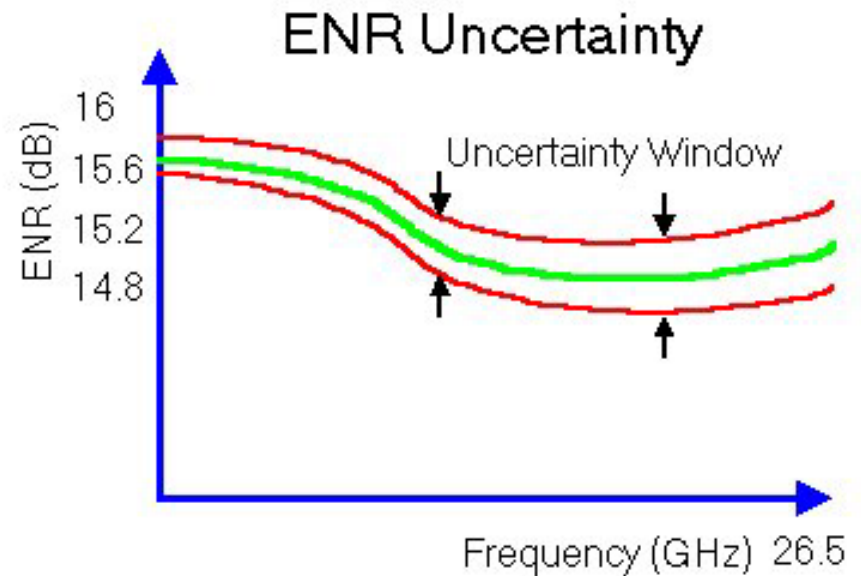
Instrumentation uncertainty

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



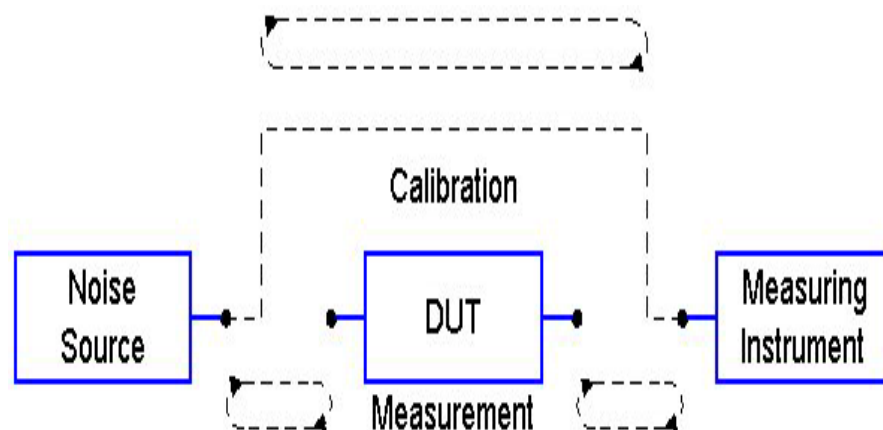
Excess Noise Ratio (ENR) uncertainty

- 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



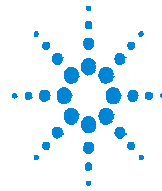
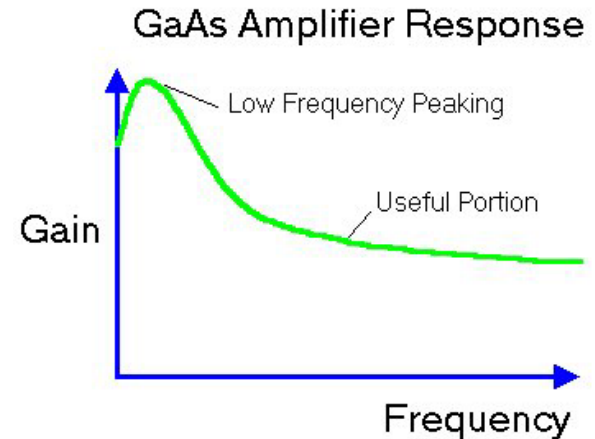
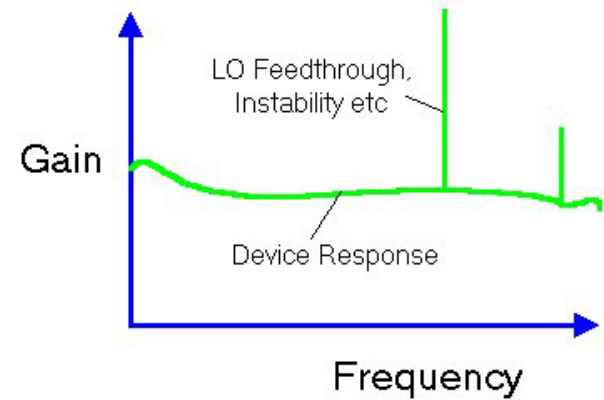
Mismatch uncertainty

- 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

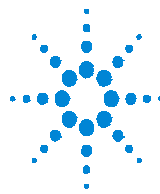
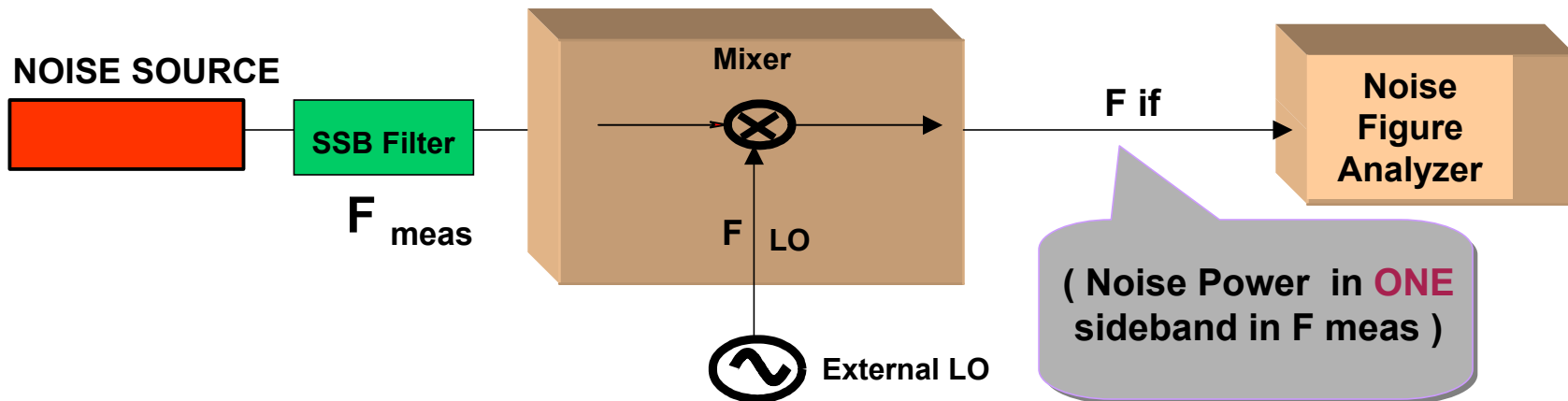
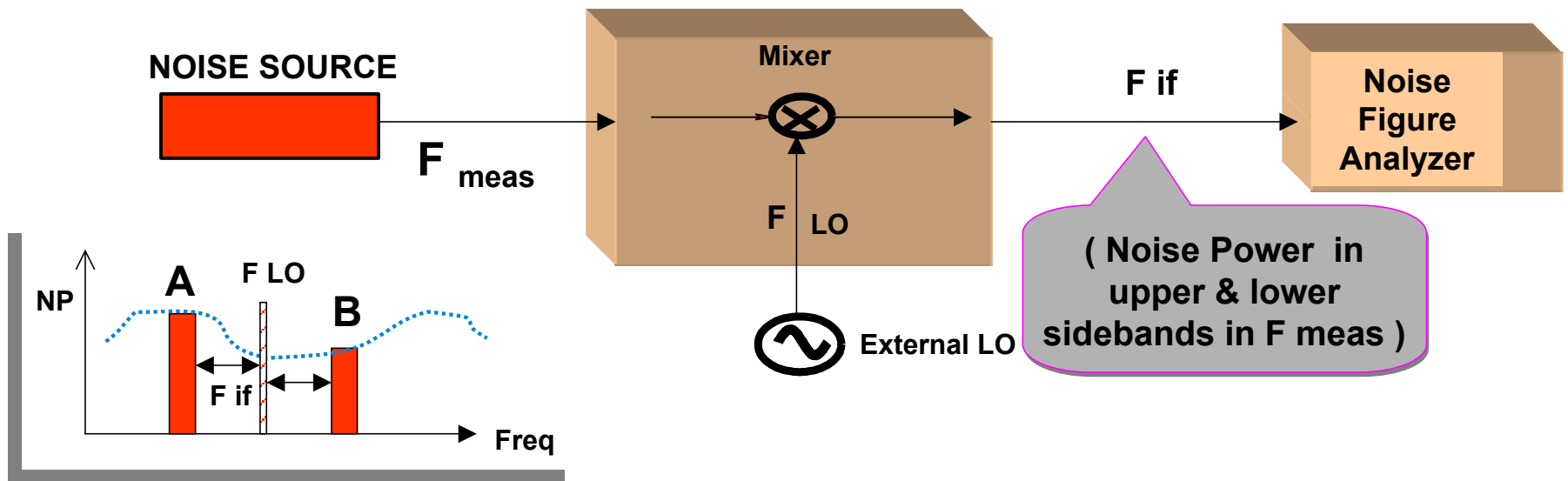


Unwanted in-band power

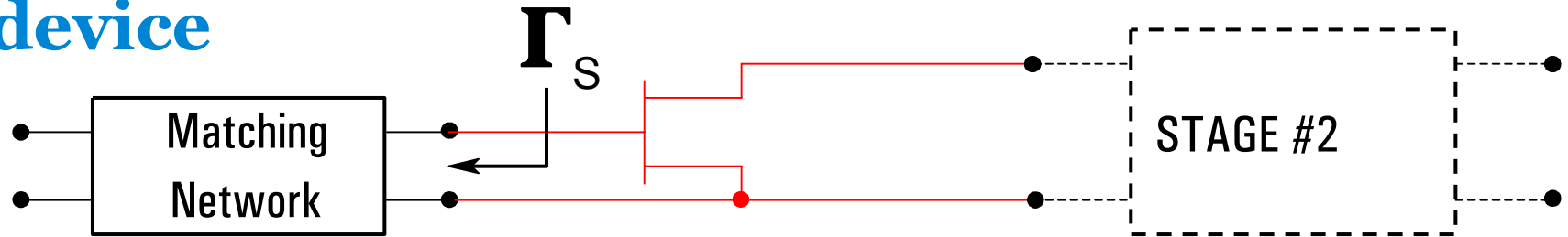
- High levels of unwanted in-band power will cause the analyzer to select a poor range for the measurement
- High instrument noise figure
- Keep LO's well out of the band of the instrument
- Ensure devices are stable and free from oscillations
- Filter unwanted amplifier responses



Mixer measurements (SSB v DSB)



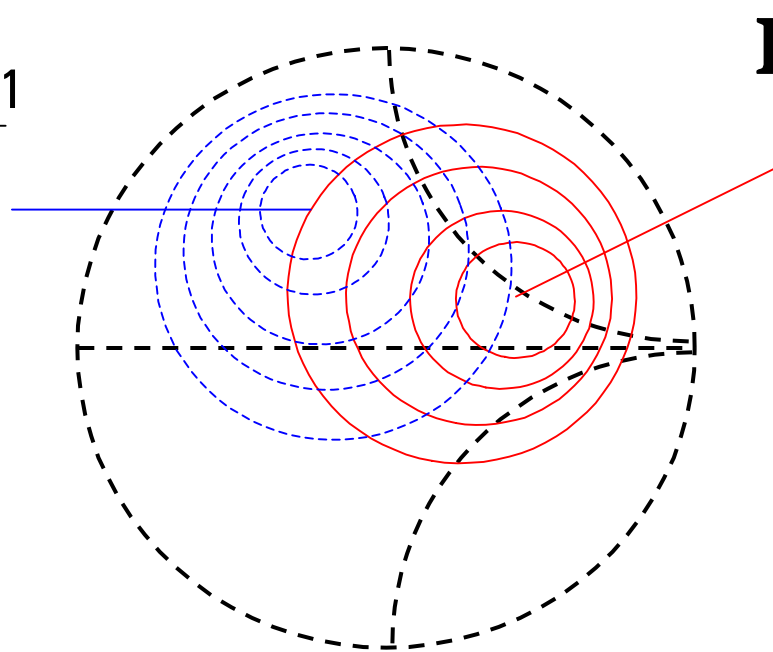
Gain and noise figure of the device



$$\Gamma_{\text{MAX}} = 0.64 \quad \angle 101$$

$$F = 3.37 \text{ dB}$$

$$G_{\text{a}} = 0.53 \text{ dB}$$



$$\Gamma_{\text{OPT}} = 0.43 \quad \angle 23$$

$$F = 1.45 \text{ dB}$$

$$G_{\text{a}} = -2.77 \text{ dB}$$



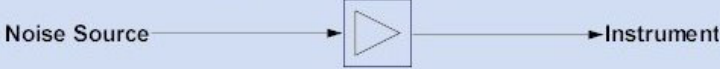
Web based measurement uncertainty calculator

Data Entry

Calculator Tabular Results Graphical Results

Press this to reset the form to default values

Device Under Test Amplifier Frequency Convertor

Noise Source  Instrument

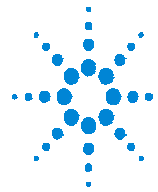
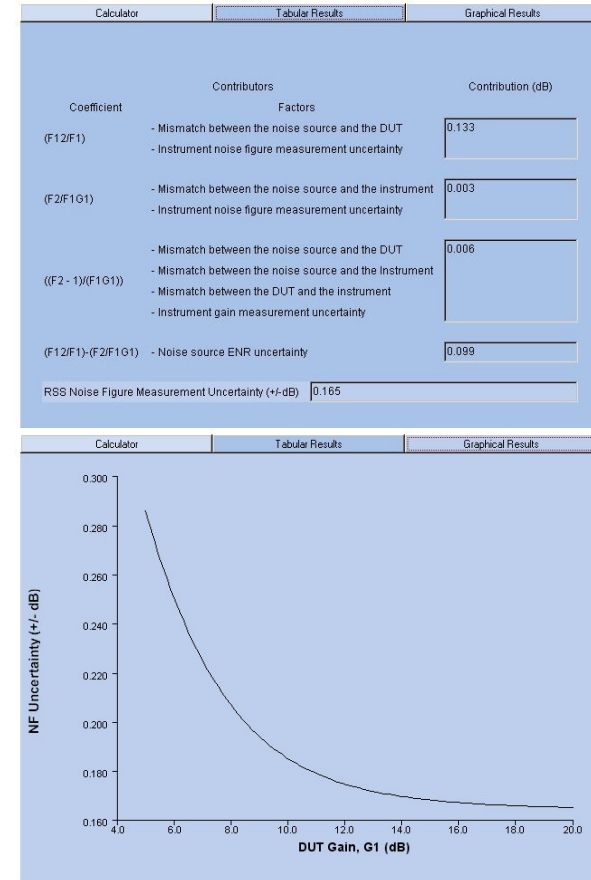
Noise Source Defaults		Instrument Defaults	
HP346 B		HP8970 B	
ENR Uncertainty (+/-dB)	DUT Noise Figure, NF1 (dB)	Noise Fig. Uncertainty (+/-dB)	
0.1	3	0.05	
NS Match *	DUT Gain, G1 (dB)	Gain Uncertainty (+/-dB)	
1.15	20	0.15	
	DUT Input Match *	Instrument Noise Fig, NF2 (dB)	
	1.5	5	
	DUT Output Match *	Instrument Match *	
	1.5	1.8	

Parameter Lower Value Upper Value Number of Points

Sweep

* This term can be entered in dB(Sxx), VSWR or as a reflection coefficient.
e.g. -15 (dB) = 1.43 (VSWR) = 0.178 (Ref. Coef.)

Results



To find out more on noise figure solutions:

Agilent Home HP Products HP Services & Support HP.com Home

Agilent Test & Measurement

SEARCH
ASSISTANCE
T & M HOME

Product Information
Services
Technical Support
How To Buy
Applications

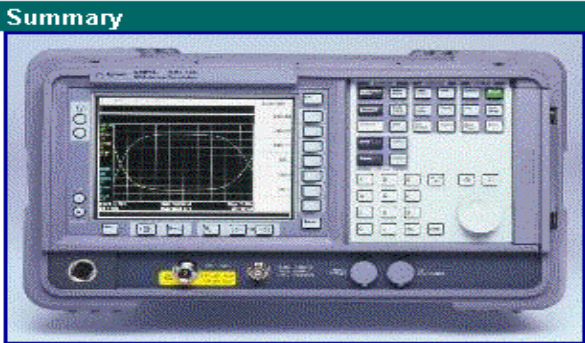
What's New
Publications
Special Interest
Events
Country

Sign Up
Sign In/Sign Out

Product Information

Agilent N8973A Noise Figure Analyzer 10MHz to 3GHz

Summary



The N8973A provides all the functionality and reliability you've come to expect from the leader in noise figure measurement and then takes a giant leap forward in accuracy, flexibility, and ease of use.

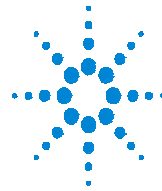
Product Details
[Brochure](#) (PDF)
[Technical Specification](#) (PDF)
[Key Specifications](#)

Additional Information
Check here for related product, application, and support information for this product.
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[Agilent N8973A Technical Support](#)

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