MMIC Design and Development

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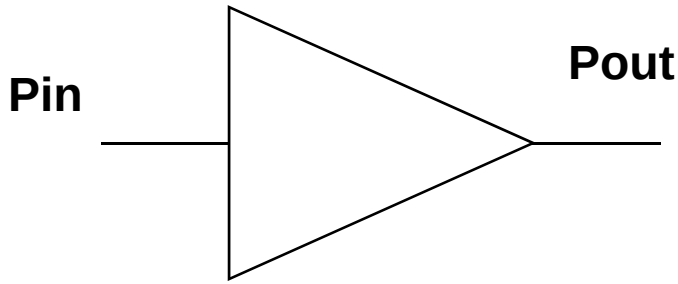
Types of Measurements

- Swept Frequency
  - Power, Gain, Match
  - Noise Figure
- Single Frequency
  - Amplitude and PhaseLinearity
- DC
  - Input power and efficiency

Power

- **Standard unit of Power is Watt**
  - **milliwatt is 10^{-3}Watt**
- **dB scale is used to compress the scale when working over a wide range of power level**
  - **Power in dBW = $10\log_{10}$(Power in watts)**
  - **Power in dBm = $10\log_{10}$(Power in milliwatts)**

Gain or Loss



Amplifier

Gain = Pout / Pin

Or

Gain (dB) = Pout(dB) – Pin(dB)

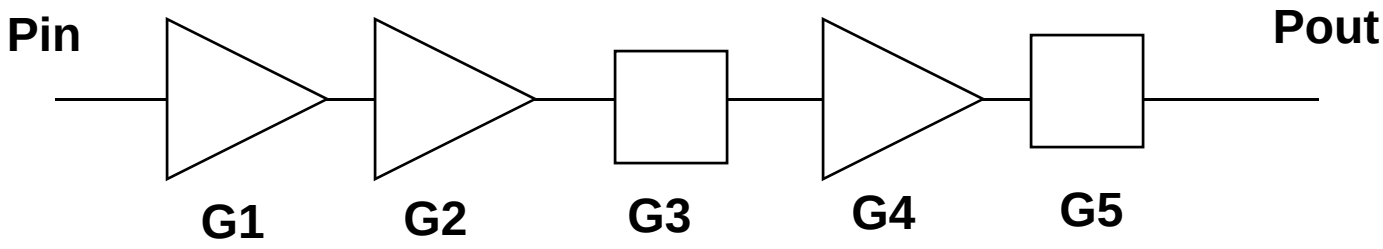
Lossy Element

Gain = Pout / Pin < 1

Or

Gain (dB) = Pout(dB) – Pin(dB) < 0

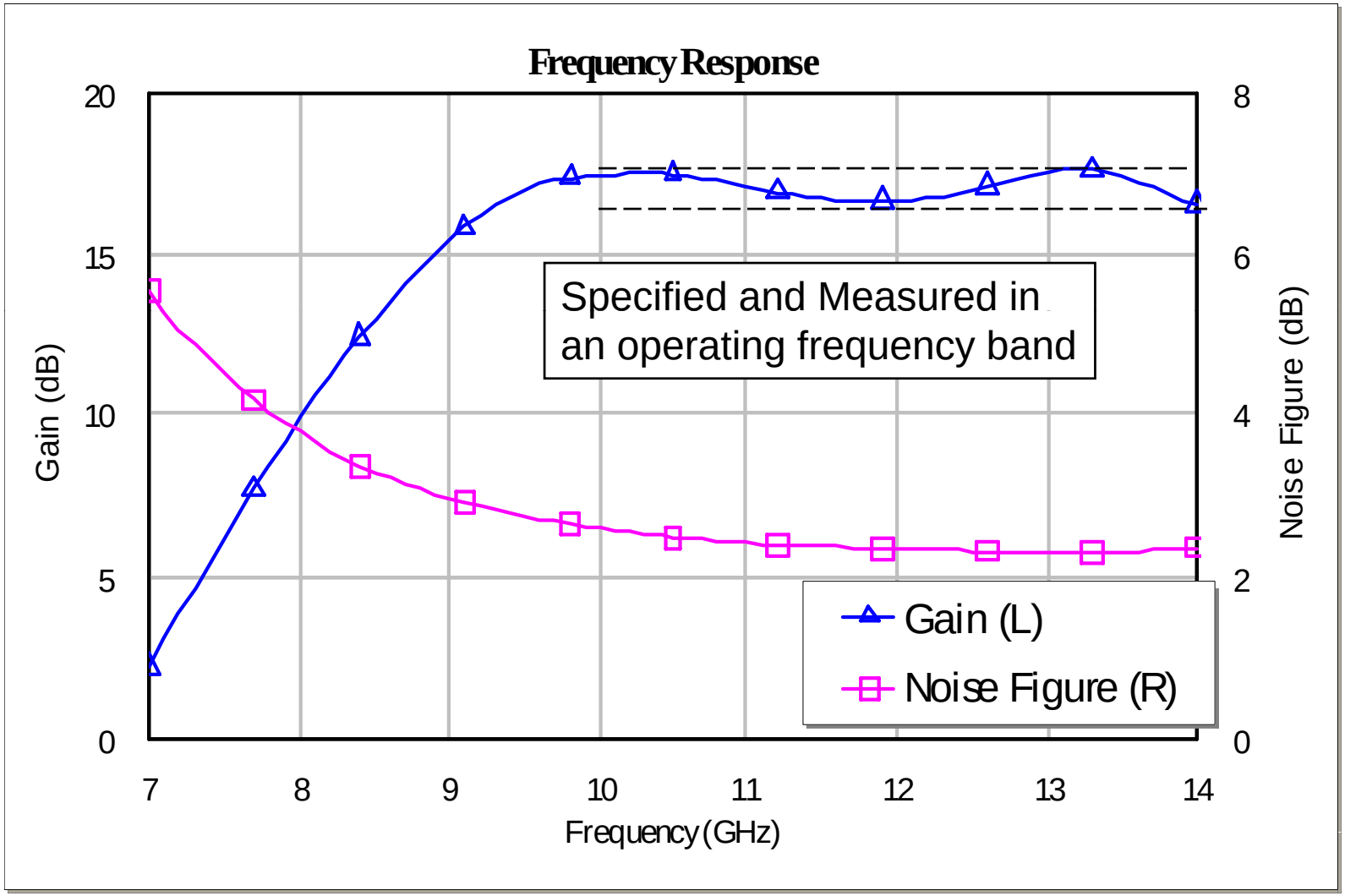
Cascaded Elements



Pout = Pin*G1*G2*G3*G4*G5 In natural units

Pout = Pin+G1+G2+G3+G4+G5 In dB

Gain Ripple


Frequency Response
Gain (dB)
Noise Figure (dB)
Frequency (GHz)
20
15
10
5
0
8
6
4
2
0
7
8
9
10
11
12
13
14
Specified and Measured in an operating frequency band
Gain (L)
Noise Figure (R)

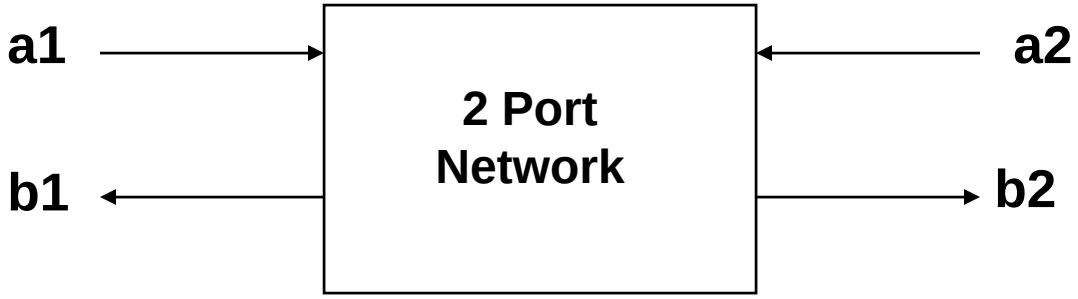
Match

- Measure of reflection at an interface
  - Reflections due to mismatch in impedance at the Input or Output of a device
- Reflection coefficient ρ
- VSWR
- Return loss

Match

	If $Z_L = Z_0$	If $Z_L = 0$
$\rho = \frac{Z_L - Z_0}{Z_L + Z_0}$	$\rho = 0$	-1
$VSWR = \frac{1 + \lvert\rho\rvert}{1 - \lvert\rho\rvert} : 1$	VSWR = 1:1	infinite:1
Return Loss = $-20 \log_{10} (\lvert\rho\rvert)$	Return Loss = -infinite	0dB

S Parameters

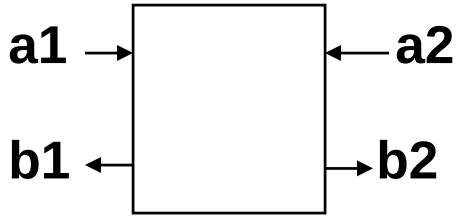


$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$

Extend to any number of ports
n ports is and n x n S matrix

Interpretation of S_{ij}

$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$



For matched load on port 2

$$a_2 = 0$$

$$S_{11} = \frac{b_1}{a_1}$$

$$S_{21} = \frac{b_2}{a_1}$$

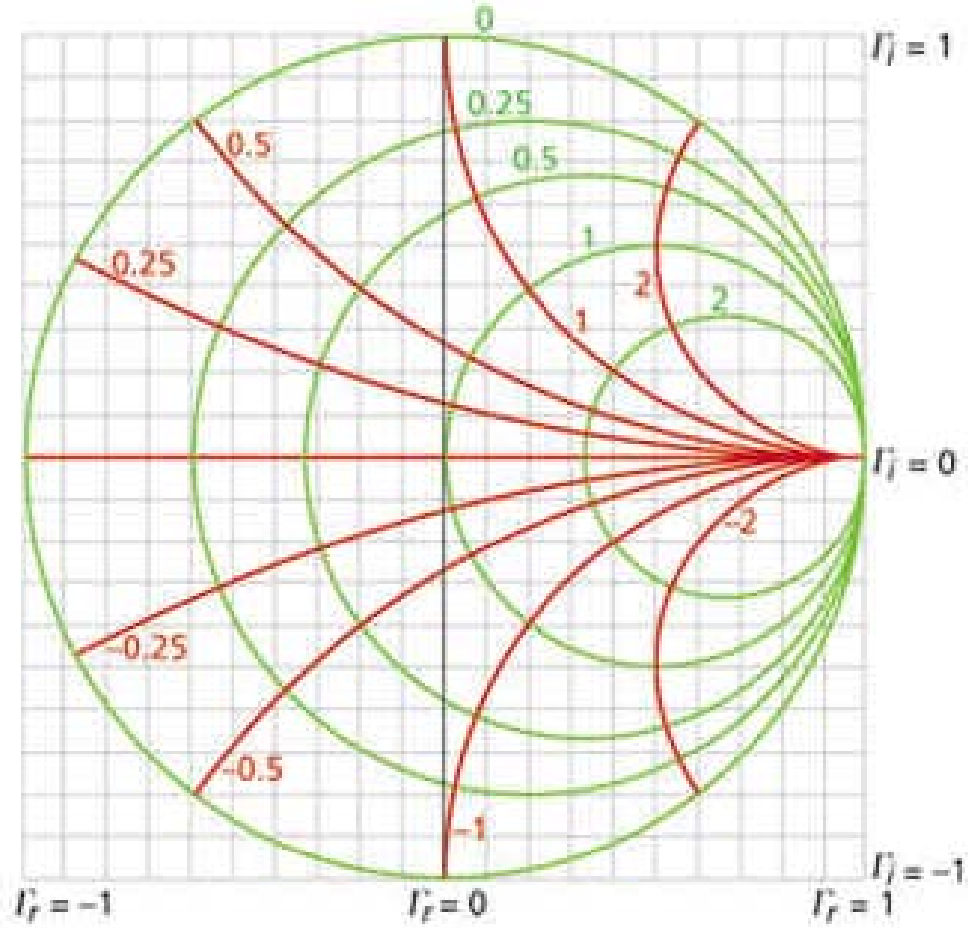
For matched load on port 1

$$a_1 = 0$$

$$S_{12} = \frac{b_1}{a_2}$$

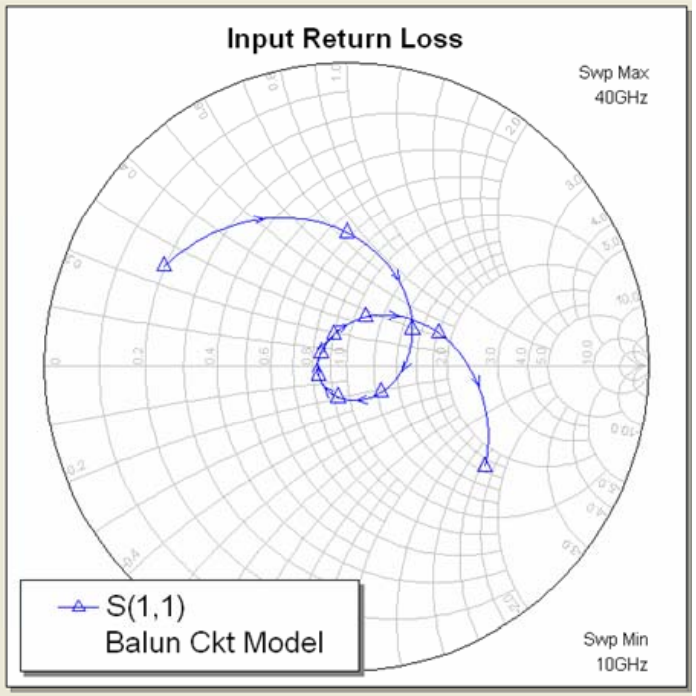
$$S_{22} = \frac{b_2}{a_2}$$

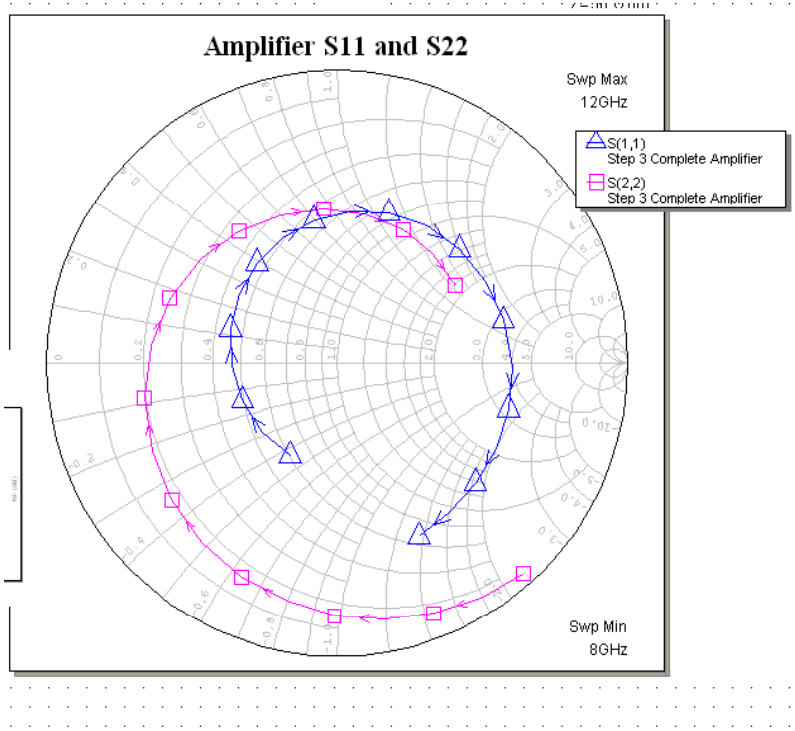
Smith Chart



http://www.web-ee.com/primers/files/SmithCharts/smith_charts.htm

Smith Chart Examples





Noise Figure

- Noise figure is a measure of the amount of noise added by a device
- Measure noise power output of a device with the input terminated in a matched load.

Noise Figure in dB

Gain in dB

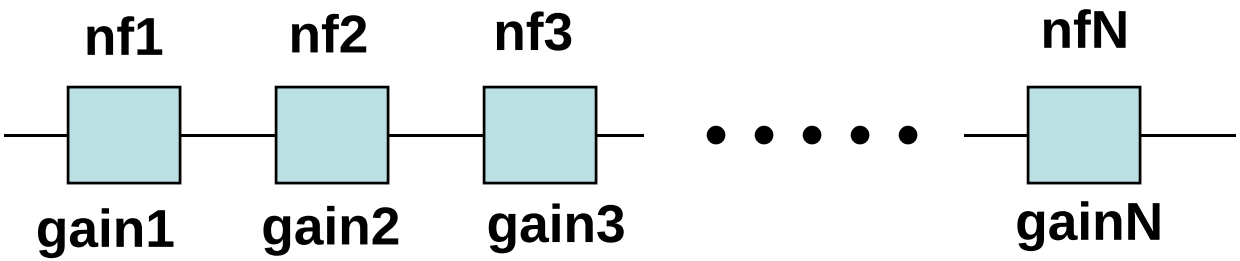
Noise power output

$$NPO(dBm) = kTB + NF + G$$

$$kTB(dBm) = -114 + 10Log_{10}(B)$$

Bandwidth in MHz

System Noise Figure



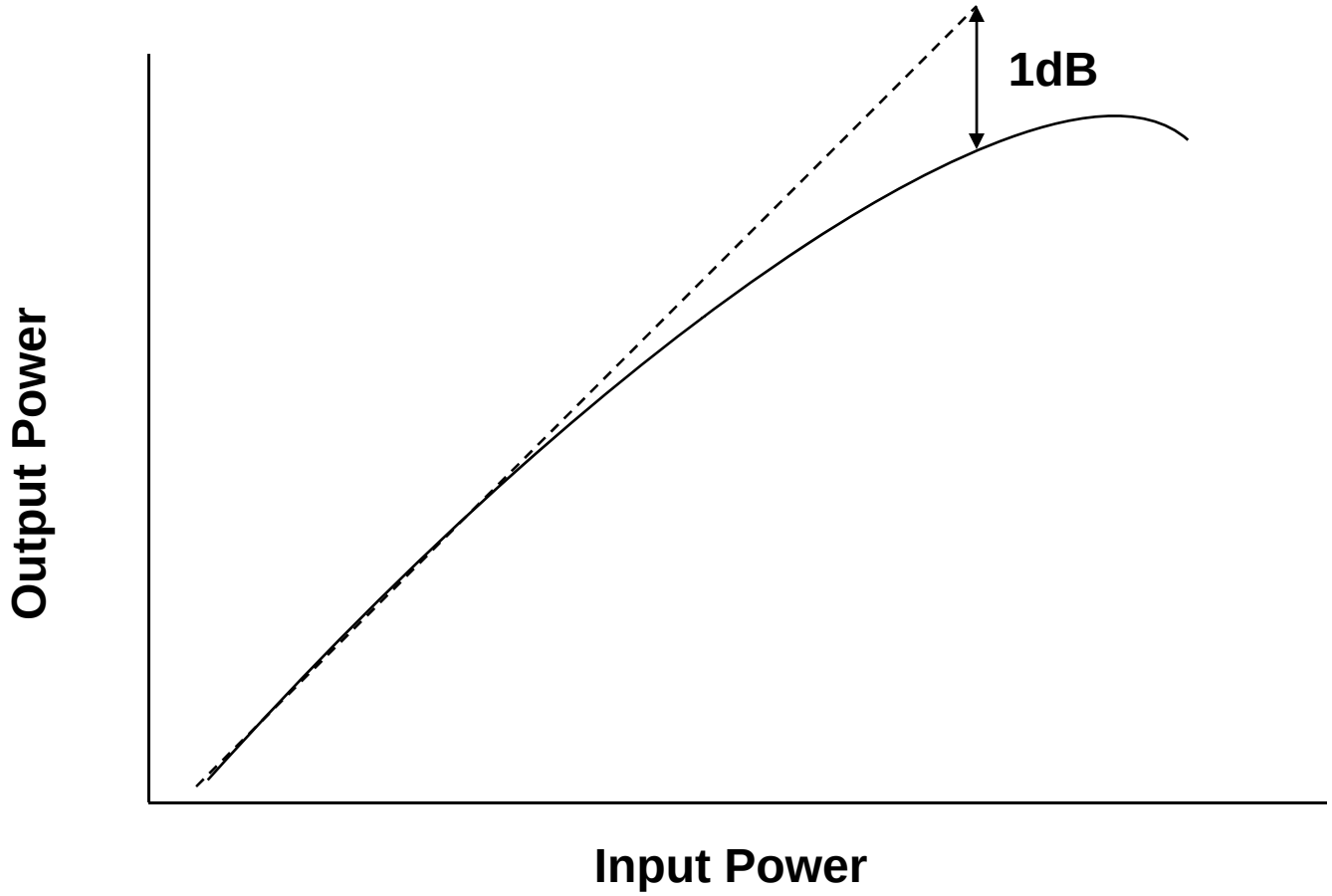
$$nf_{system} = nf_1 + \sum_{i=2}^{N} \frac{nf_i - 1}{\prod_{i=1} gain_j}$$

Natural units

$$NF\ (dB) = 10\mathrm{Log}_{10}(nf)$$

$$GAIN\ (dB) = 10\mathrm{Log}_{10}(gain)$$

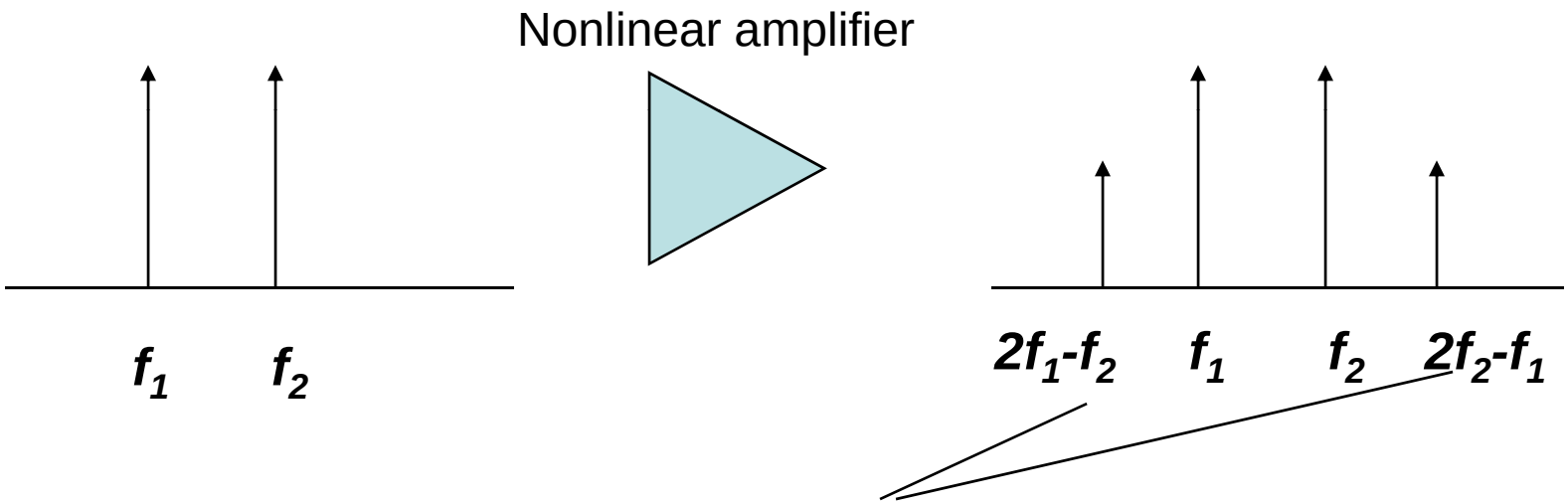
Amplitude Linearity



Multicarrier Effects

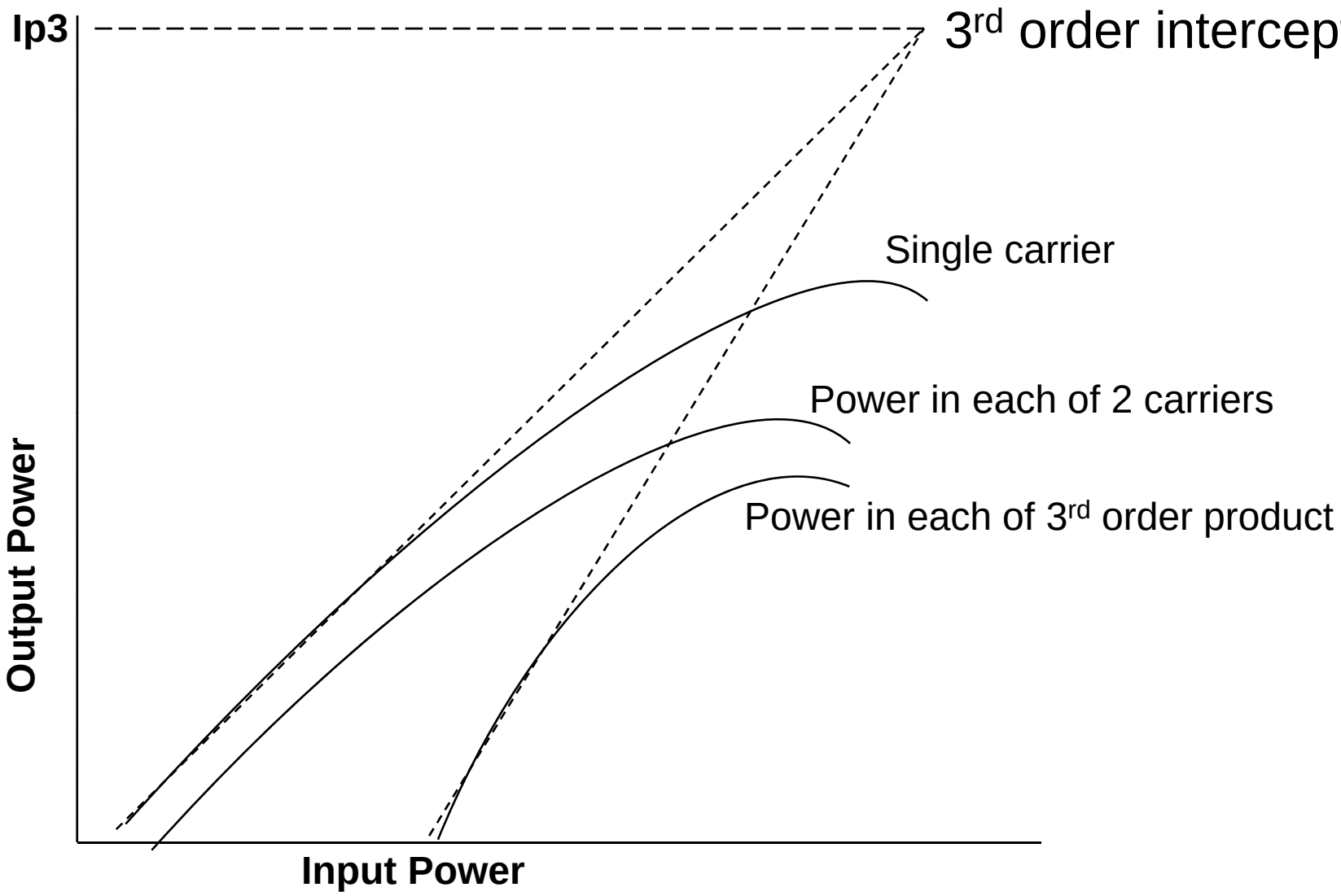
2 pure signals f_1 ***and*** f_2

multiple signals emerge



3rd order intermodulation products

Higher order intermodulation products also present



P3rd-order = Ptones@output - 2 · (IP3 - Ptones@output) {dBm}

More IP3

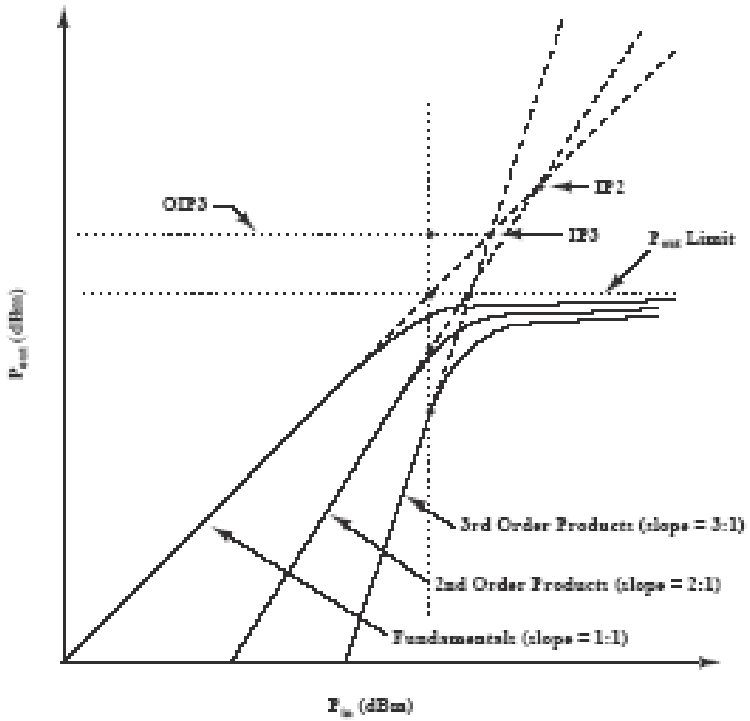


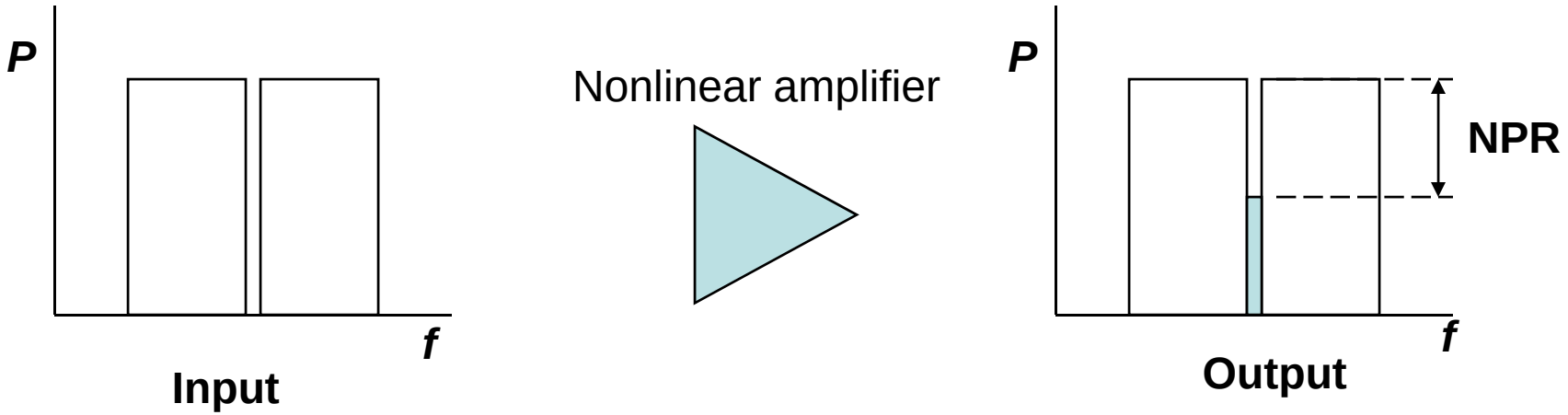
Figure 1

P3rd+3(IP3-P1st)=IP3

http://www.testedgeinc.com/docs/ip3.pdf

Noise Power Ratio

- Measure of intermodulation products when many carriers are present
- A measurement is made using a noise source and notch filter



DC

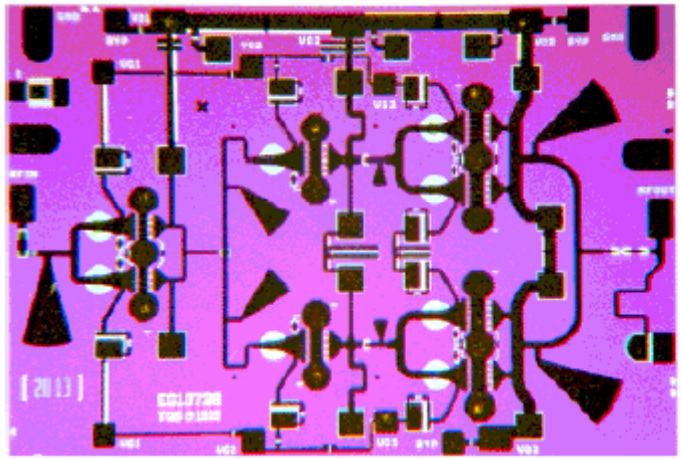
- Input power P_{DC} in Watts
- Output power P_{RF} in Watts
- Output efficiency $= P_{RF} / P_{DC}$
  - Usually expressed in percent
- Power added efficiency
  - Removes the contribution of input RF
  - PAE = $(P_{RF} - P_{RFin}) / P_{DC}$

See example data sheet

TriQuint SEMICONDUCTOR

Product Datasheet
January 17, 2005

27- 32 GHz 0.7 Watt Power Amplifier **TGA1073B-SCC**



Key Features and Performance

- 0.25 um pHEMT Technology
- 25 dB Nominal Gain @ 28 GHz
- 28.5 dBm Nominal Pout @ P1dB (7V)
- -38 dBc IMR3 @ 18 dBm SCL
- Bias 6 - 8 V @ 420 mA
- Chip Dimensions 3.12mm x 2.15mm

Primary Applications

- Point-to-Point Radio
- Point-to-Multipoint Communications

KaBand amp.pdf