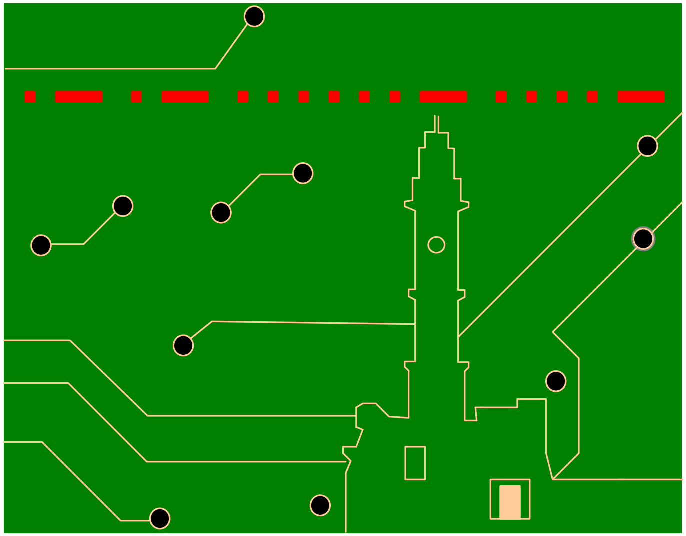
ΤΗΛ412 Ανάλυση & Σχεδίαση (Σύνθεση) Τηλεπικοινωνιακών Διατάξεων

Διάλεξη 6



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ΗΜΜΥ Πολυτεχνείου Κρήτης, Φθινόπωρο 2014

…και όμως η Γη γυρίζει…

- iCubes v0.2, designed through TEL412…
- bottom line: <u>you</u> can do it …

Lecture 6 – Cascaded Systems Revisited: Receiver RF Chain NF and IP3 example

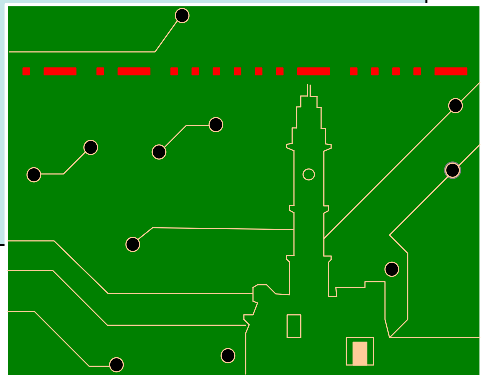
Previous lecture:

- Homodyne Receiver (and disadvantages), SuperHet Receiver, Subsampling and Digital-IF Receiver, Dynamic Range of ADC.

Today,

- Cascaded Systems, revisited:

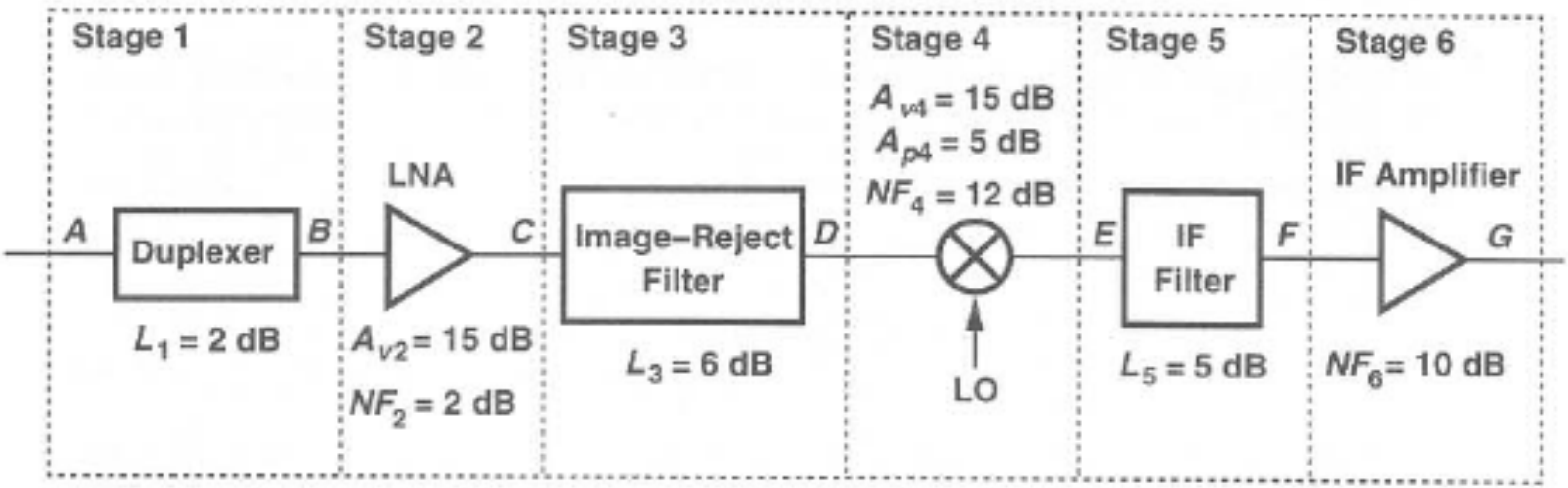
NF and IP3 example of a RF receiver chain



Διάλεξη 6

Figures/material for today’s lecture come from:
B. Razavi, RF Microelectronics, Prentice Hall 1998.

Receiver Front End - revisited

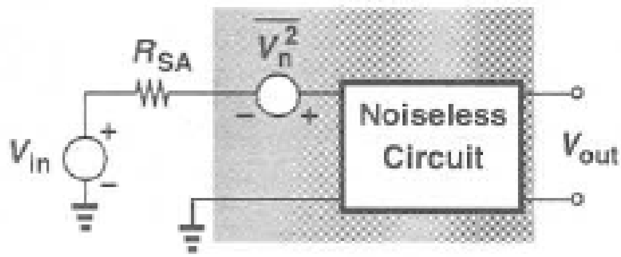


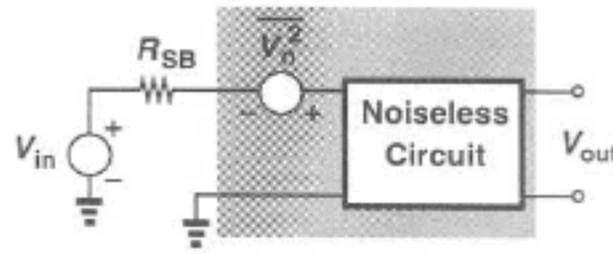
- What is the overall NF? What is the overall IP3?
- Remember that NF is referenced to a specific input resistance…
- Power Gain depends on input resistance…

$$NF_{\text{tot}} = 1 + (NF_1 - 1) + \frac{NF_2 - 1}{A_{p1}} + \cdots + \frac{NF_m - 1}{A_{p1} \cdots A_{p(m-1)}}$$

- Trick: to avoid confusion, convert all power gains to voltage-squared gains – <u>the latter are R-independent</u>!

Receiver Front End - revisited





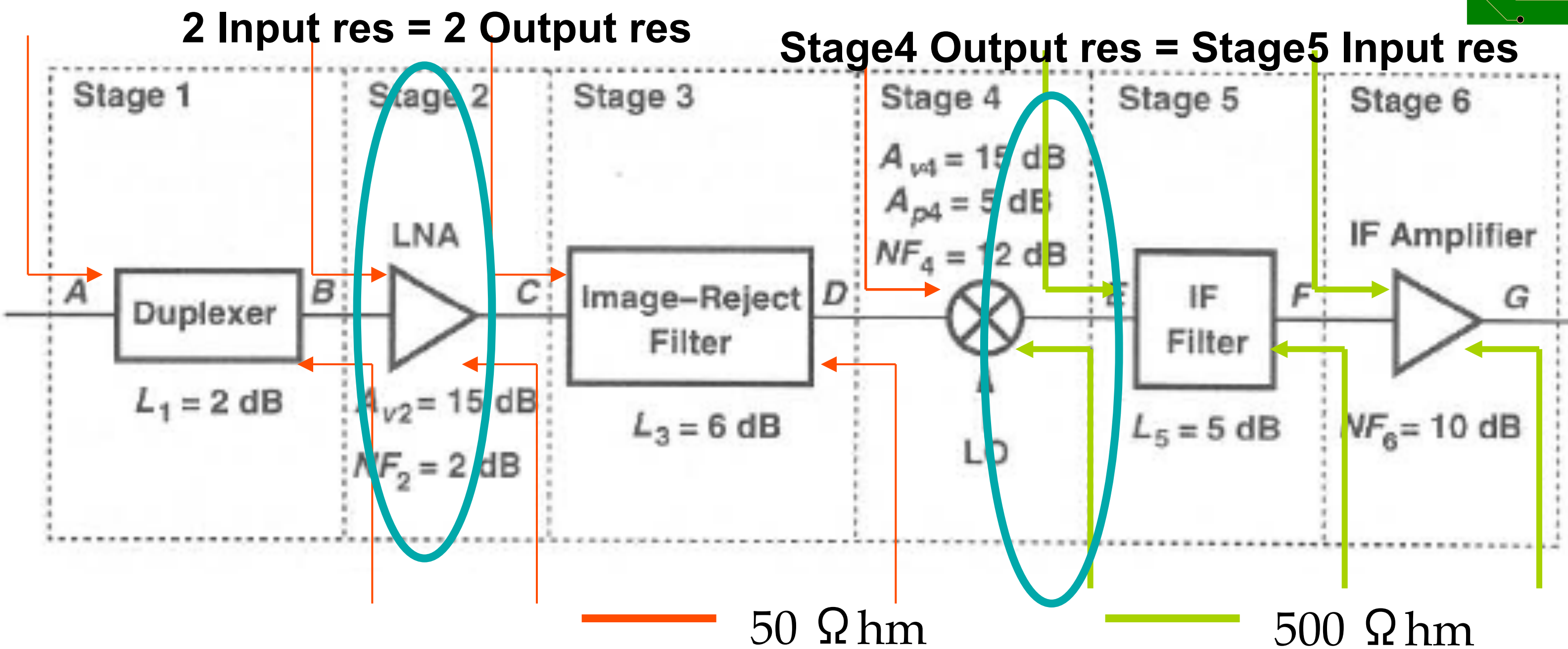
Product is R_S – independent!

- Assuming no input noise current, we have shown that:

$$NF_A = 1 + v_n^2/(4KTR_{SA})$$
$$NF_B = 1 + v_n^2/(4KTR_{SB})$$
$$\Rightarrow \quad (NF_A - 1)R_{SA} = (NF_B - 1)R_{SB}$$

- If NF is given for a specific input resistance, other that the output resistance of the previous stage, then NF value in Friss equation is divided with voltage gain squared!

Receiver Front End - revisited



- $NF_E = L_5\ NF_{LNA}$ => 5 + 10 = 15 dB = 31.6

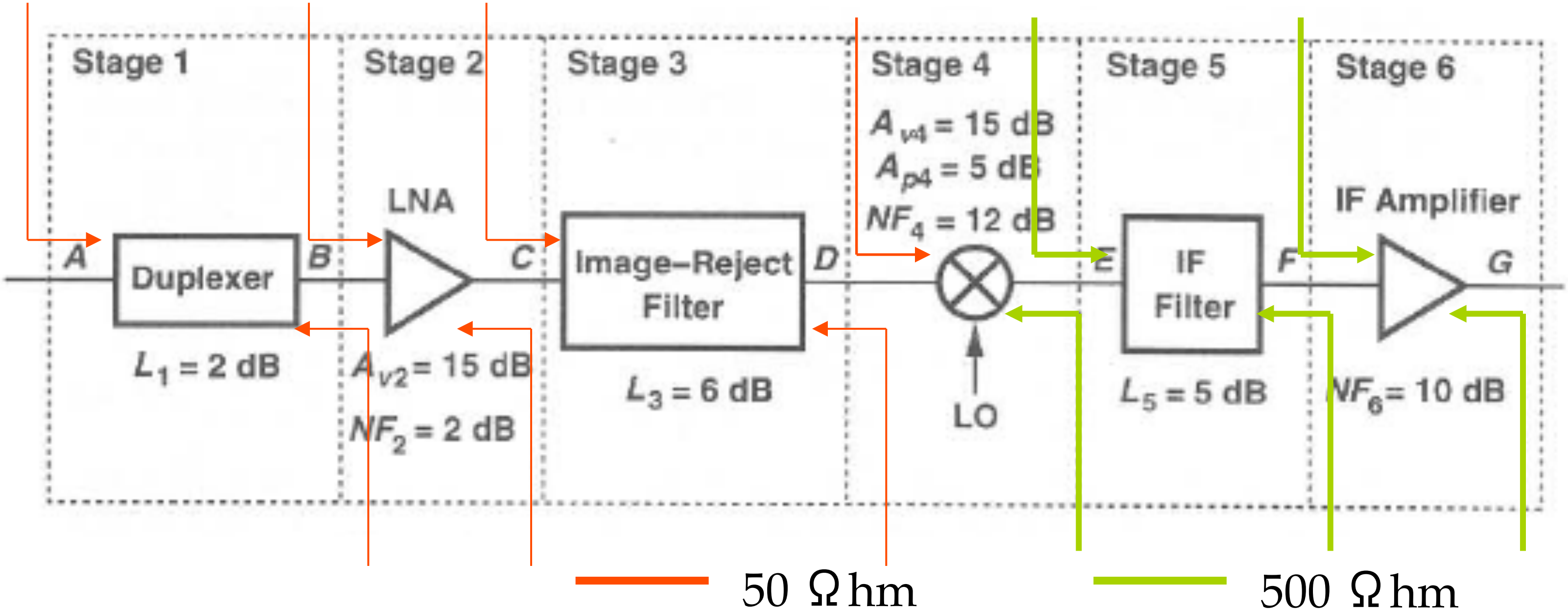
(assuming NF_6=10 dB is referenced to 500 Ωhm).

- $NF_D = NF_{LO} + (NF_E-1)/A_{p4} = 10^{1.2} + 30.6/10^{0.5} = 15.85 + 30.6/3.16 = 25.53$ = 14.1 dB.

...careful!!!

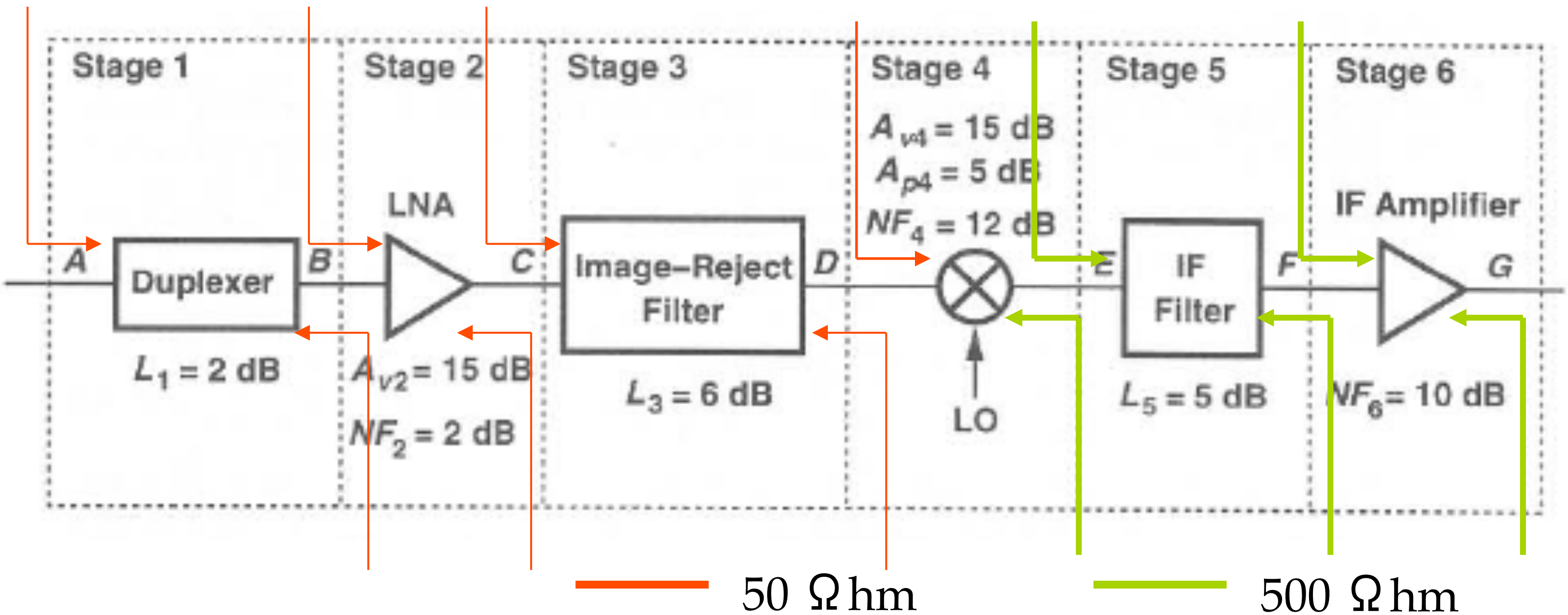
- $NF_C = L_3\ NF_D$ => 6 + 14.1 = 20.1 dB => 102.3.
- $NF_B = NF_2 + (NF_C-1)/A^2_{v2} = 10^{0.2} + 101.3/10^{1.5} = 1.58 + 3.2 = 4.78 = 6.79$ dB

Receiver Front End - revisited



- $NF_A = L_1 + NF_B = 6.79 + 2 = 8.79$ dB.
- Remember that $NF_C = 20.1$ dB…
- …confirms that initial stages of RF chain are the most NF-critical…

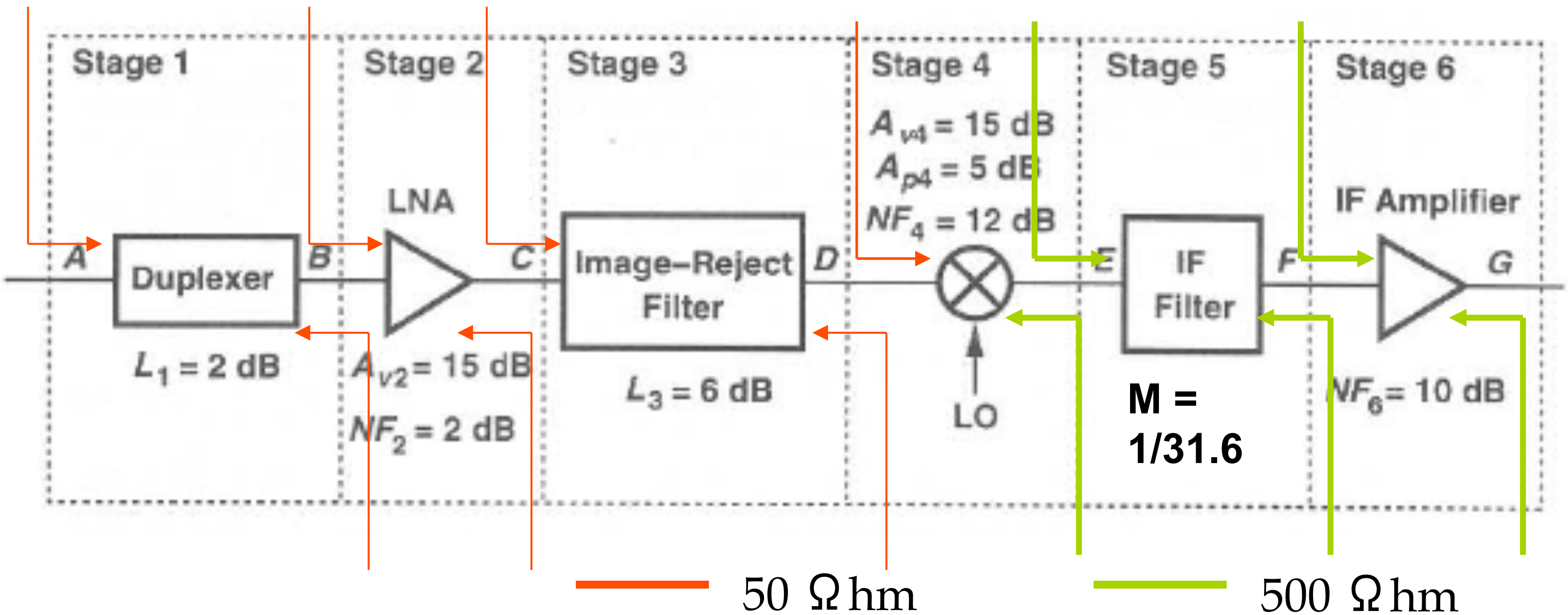
Receiver Front End - revisited



IP3: +100dBm -12dBm +100dBm +5dBm 1000Vrms 700mVrms

- What is the overall IP3?
- Stage input/output not necessarily in 50 Ωhm => use (RMS) voltage gain.
- Passive filters have tremendously large IP3.

Receiver Front End - revisited

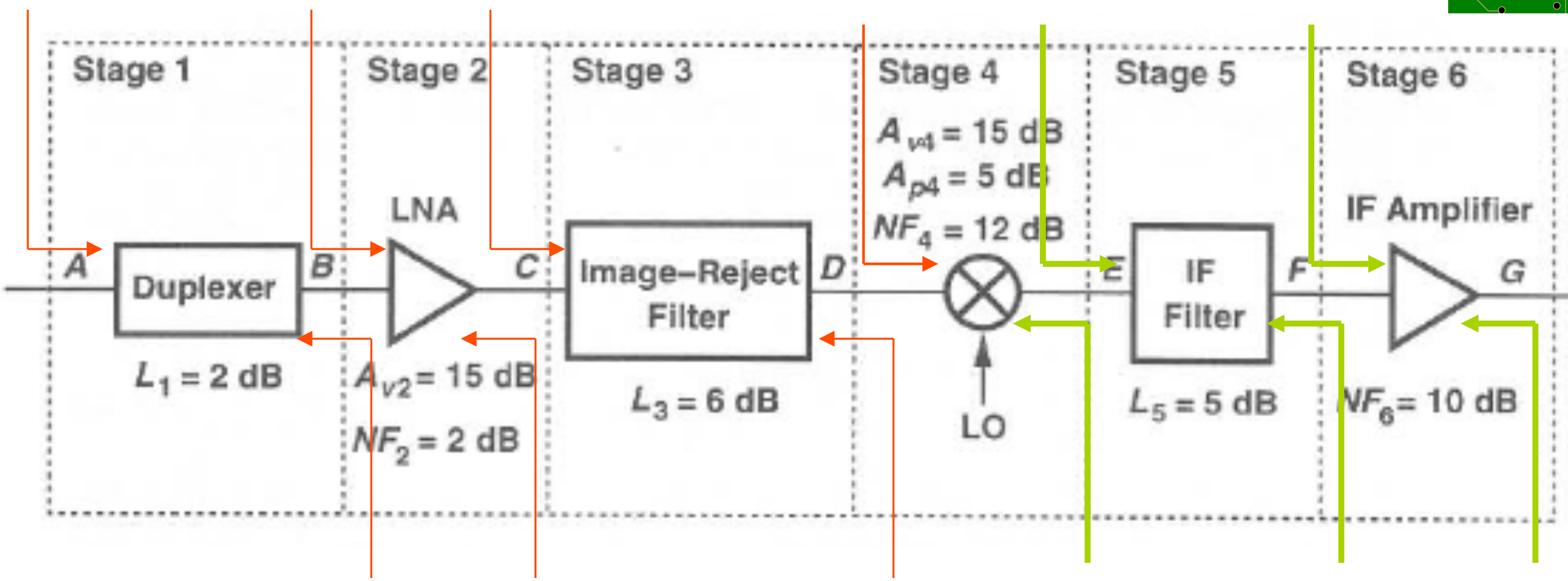


IP3: +100dBm -12dBm +100dBm +5dBm 1000Vrms 700mVrms

$$\frac{1}{IP_{3,E}^2} = \frac{1}{IP_{3,filt}^2} + \frac{M^2}{IP_{3,amp}^2} \approx \frac{M^2}{IP_{3,amp}^2} \Rightarrow IP_{3,E} = \frac{IP_{3,amp}}{M} = 22.1Vrms$$

The voltage gain of stage 5 is M=1/36 and is given!

Receiver Front End - revisited



50 Ωhm   500 Ωhm

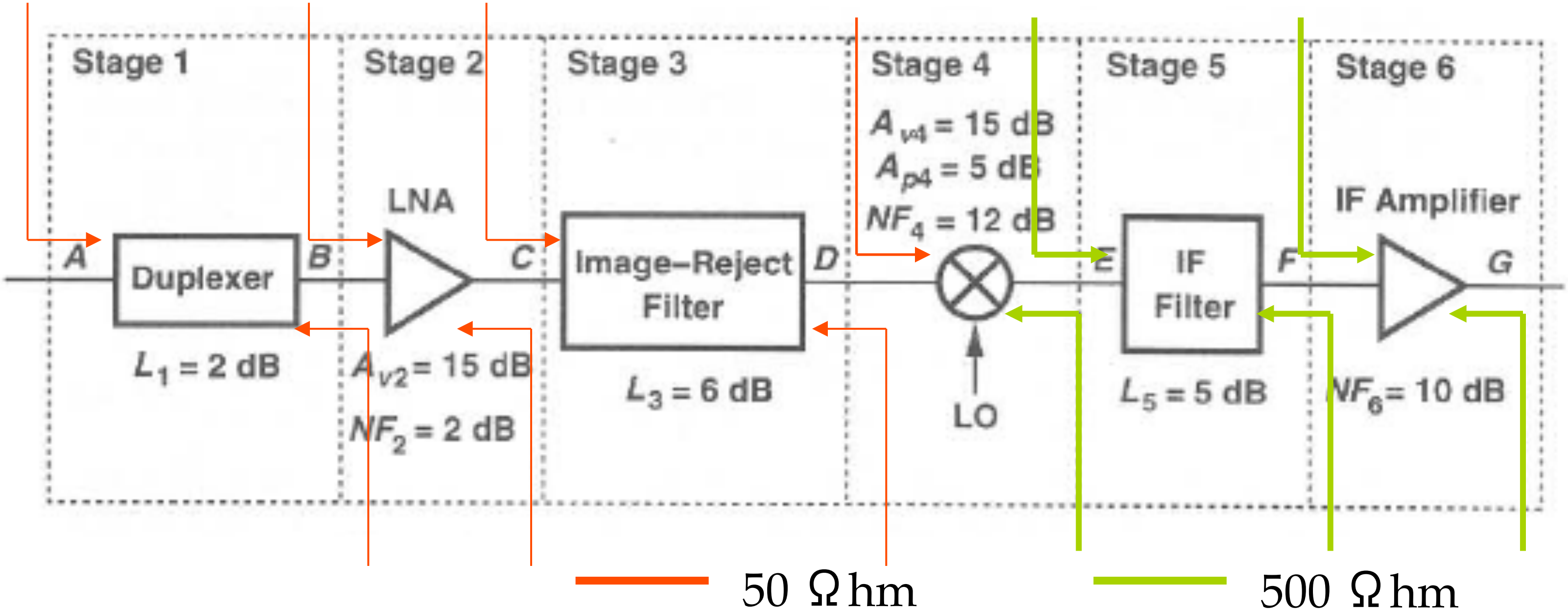
IP3: +100dBm -12dBm +100dBm +5dBm 1000Vrms 700mVrms

$$\frac{1}{IP_{3,D}^2} = \frac{1}{IP_{3,mix}^2} + \frac{A_{v4}^2}{IP_{3,E}^2} = \frac{1}{0.397^2} + \frac{5.62^2}{22.1^2} \approx \frac{1}{0.397^2} \Rightarrow IP_{3,D} = 0.397Vrms \approx +5dBm$$

IP3 = 5dBm => V^2_{rms} /50 = $10^{0.5}$mWatt => V_{rms} = 0.397 Vrms = 397mVrms

A_{v4}=15 dB => $A_{v4}=10^{15/20}$=5.62

Receiver Front End - revisited



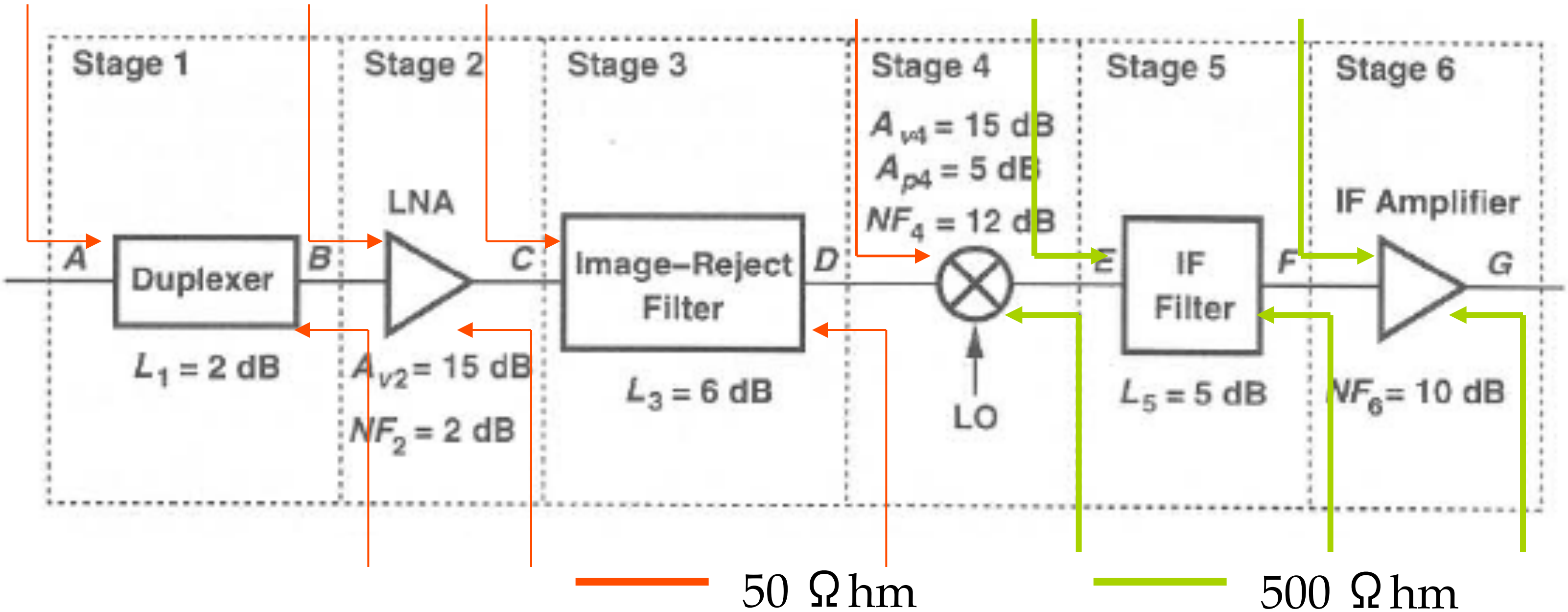
IP3:	**+100dBm**	**-12dBm**	**+100dBm**	**+5dBm**	**1000Vrms**	**700mVrms**
A_v:	**-2dB**	**+15dB**	**-6dB**	**+15dB**		**(voltage gain)**

$$\frac{1}{IP_{3,C}^2} = \frac{1}{IP_{3,filt3}^2} + \frac{A_{v3}^2}{IP_{3,D}^2} \approx \frac{A_{v3}^2}{IP_{3,D}^2} = \frac{0.5^2}{397^2} \Rightarrow IP_{3,C} = 796mVrms \approx +11.03dBm$$

A_{v3} = - 6 dB => $A_{v3} = 10^{-6/20} = 0.5$

Notice that $IP_{3,c} \approx IP_{3,F}$

Receiver Front End - revisited



IP3: +100dBm -12dBm +100dBm +5dBm 1000Vrms 700mVrms

A_v: -2dB +15dB -6dB +15dB (voltage gain)

- Similarly for other two input stages… eventually, IP3,A = -10.6dBm

Questions?