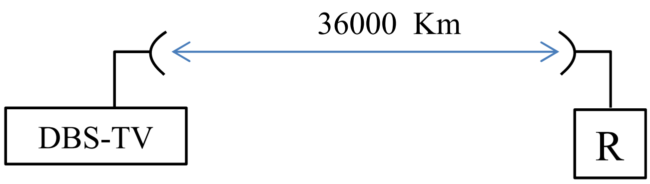
RF SYSTEMS
Written Test of September 14th, 2015

Surname & Name	
Identification Number	
Signature	

Exercise 1

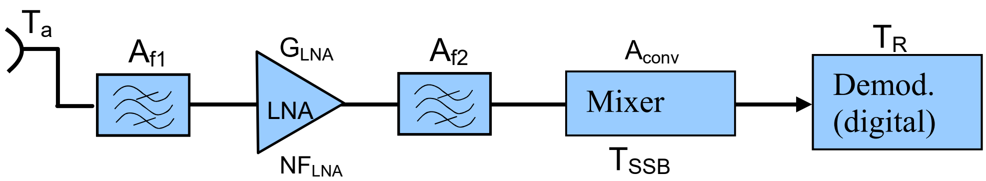


The link in the figure refers to a Direct Broadcast Satellite for TV distribution, which operates at 12.5 GHz. The beamwidth generated by the satellite antenna is 5° (electrical efficiency η=0.75) and the transmitted power is 150 W. The receiving antenna R is a parabolic dish with 2m diameter (aperture efficiency e_a=0.6).

Assume the signal bandwidth B=24 MHz and the data rate R=30 Mbit/sec. Both antennas are directed for the maximum directivity.

1) Evaluate the gain G of the antennas
2) Evaluate the received power at the receiving antenna output (R)
3) It is known the requested ratio E_b/N_0=22 dB. Evaluate the equivalent input temperature T_{eq} of the receiver (R)

Consider the following scheme for the receiver (R):

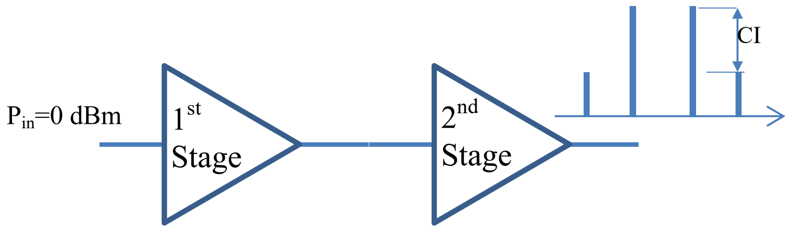


T_a=50°K
A_{f1}=1 dB
A_{f2}=1 dB
NF_{LNA}=1.5 dB
A_{conv}=7 dB
T_{SSB}=300°K
T_R=150°K

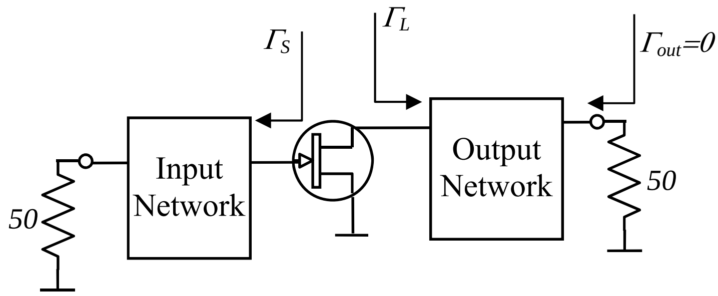
4) Evaluate the minimum value of the LNA gain (G_{LNA}) in order to obtain the requested T_{eq}.

Exercise 2

Consider a power amplifier constituted by the cascade of two stages.
The requested output mean power is 33 dBm with a carrier-to-intermodulation ratio CI=30 dB (2-tone test). The input mean power is 0 dBm. It is assumed that the gain of the 2nd stage is 15 dB and the P_{1dB} of the 1st stage is 20 dBm.
Evaluate the gain of the 1st stage and the IP3 parameter of the 2nd stage in order to satisfy the specifications. What is the Peak Envelope Power (PEP) at the nominal power output?



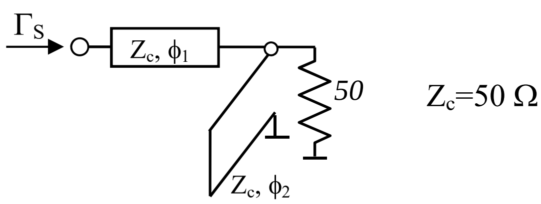
Exercise 3



$S_{11}=0.5454\angle{-106.4°}$
$S_{12}=0.1516\angle{37.6°}$
$S_{21}=1.972\angle{95.3°}$
$S_{22}=0.7133\angle{-35.5°}$

The scheme represents an amplifier that must provide a transducer gain G_T=10 dB and must be matched at output.

1) Using the scattering parameters in the figure, evaluate the possible values of Γ_S and Γ_L that satisfy the gain requirement.
2) Design the input network (i.e. compute the electrical lengths ϕ_1 and ϕ_2) according the following scheme:



Solution

Exercise 1

Wavelength: λ=300/f_0=24 mm
Transmitting antenna gain:

$$G_T = \frac{2\eta}{1-\cos(\theta_b/2)} = 1576 \quad (32 \text{ dB})$$

Receiving antenna gain:

$$G_R = A_e \frac{4\pi}{\lambda^2} = e_a \left(\frac{\pi d}{\lambda}\right)^2 = 41123.35 \ \ (46.14 \text{ dB})$$

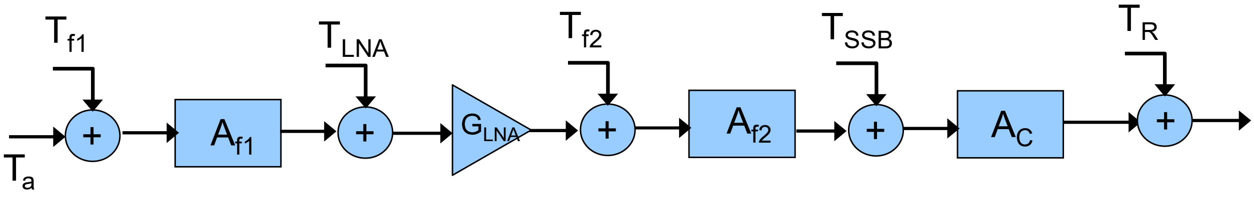
Link equation (in dBW):

$$P_r = P_t + 20\log\left(\frac{\lambda}{4\pi R}\right) + G_T + G_R = -105.6 \text{ dBW}$$

Evaluation of T_{eq}:

$$P_r - 10\log\left(KT_{eq}B\right) = \left(\frac{E_b}{N_0}\right)_{dB} + \left(\frac{R}{B}\right)_{dB} \Rightarrow T_{eq} = 416.67 \text{ °K}$$

LNA Gain:



A_{f1}= A_{f2}=1.259 A_c=5.01 $\quad T_{f1} = T_0\left(10^{A_{f1}/10} - 1\right) = 75.86 = T_{f2} \qquad T_{LNA} = T_0\left(10^{NF_{LNA}/10} - 1\right) = 120.87$

$$T_{eq} = T_a + T_{f1} + A_{f1}T_{LNA} + \frac{A_{f1}\left[\left(T_{SSB} + A_c T_R\right)A_{f2} + T_{f2}\right]}{G_{LNA}} = 416.67$$

$$G_{LNA} = \frac{A_{f1}\left[\left(T_{SSB} + A_c T_R\right)A_{f2} + T_{f2}\right]}{416.67 - \left(T_a + T_{f1} + A_{f1}T_{LNA}\right)} = 25 \ \ (14 \text{ dB})$$

Exercise 2

Equivalent amplifier:

G_{eq}, $IP3_{eq}$

$$G_{eq} = G_1 + G_2 = 33 - 0 = 33 \text{ dB} \quad \Rightarrow \quad G_1 = 33 - G_2 = 18 \text{ dB}$$

$$IP3_1 = P_{1dB} + 10.67 = 30.67 \text{ dBm}$$

$$\frac{1}{IP3_2} = \sqrt{\left(\frac{1}{IP3_{eq}}\right)^2 - \left(\frac{1}{IP3_1}\right)^2} = 1.6294 \cdot 10^{-5} \Rightarrow IP3_2 = 47.88 \text{ dB}$$

For a 2-tone signal PEP is 3 dB higher than Pm, then PEP=36 dBm.

Exercise 3

Using the electronic Smith Chart the constant Available Power Gain circle with Gav=10 dB is drawn. Then a point on this circle is selected which represents Γs; for instance $\Gamma s = 0.165\angle 131°$. Imposing the output matching, the value of Γ_L determining the transducer gain equal to Gav=10 dB is obtained: $\Gamma_L = 0.743\angle 39.027°$.

With the above value of Γs the parameters of the input matching network result:
$\phi 1 = 65.1°$, $\phi 2 = 108.42°$